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ABSTRACT

This document contains separate reviews of recent developments in science and mathematics education research. These literature reviews note those issues that were carefully examined and identify others which had not received attention. Although the reviews concentrated on Australian research, relevant studies in other countries such as the United Kingdom and the United States were also examined. A two-dimensional grid or matrix was established as a guide to the reviews. The first dimension used is level of schooling (primary, secondary, tertiary). The second dimension concerns subject of research (provision, participation, and outcomes). The three areas in the second dimension are further divided as follows: (1) provision (amount-- how much is taught; curriculum-- what is taught; teacher education-- who teaches; support mechanisms-- what systemic assistance is given); (2) participation (who takes part in learning); (3) outcomes (cognitive-- knowledge-based outcomes; investigatory-- skill-based outcomes; affective-- attitudinal outcomes; transition-- expected/actual outcomes of students in transition from level to level; exit-- expected/actual outcomes of students in transition from school to community life, including work and leisure). Thus, 30 different elements represented in the matrix are examined in the reviews. Bibliographies are also provided at the end of each review. (JN)

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A REVIEW OF RECENT RESEARCH IN SCIENCE AND MATHEMATICS EDUCATION WITH PARTICULAR REFERENCE TO AUSTRALIA

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JUNE 1983

Centre for Program Evaluation
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PREFACE

This document contains two reviews; one relates to recent developments in science education research, the other to recent developments in mathematics education research. The reviews were assembled to assist the development of a study of the needs for future research in these areas, commissioned by the Victorian Post Secondary Education Commission (VPSEC) in October 1982.

The reviews were carried out so that we could note issues which had been carefully examined, and to identify others which had not received attention. Although the reviews concentrated on Australian research, relevant studies in other countries such as the United Kingdom (UK), and the United States of America (USA) were also examined. Due to the size of the task we concentrated on studies published during the past five years.

To guide the literature reviews, a two dimensional grid or matrix was established. The first dimension used was level of schooling; primary, secondary and tertiary. The second dimension concerned the subject of the research. There were three major sections along this dimension; provision, participation and outcomes.

In each of these sections, subdivisions were made as outlined in Figure 1. Within the section on provision, the four subsections were: amount, curriculum, teacher education, and support mechanisms. Within the section on outcomes the five subsections were: cognitive, investigatory, affective, transition from one level of schooling to another and transition from schooling to community life. Thus, there were 30 elements in the matrix.

The literature reviews are presented in Sections S (Science) and M (Mathematics). The numbering scheme used in these appendices follows that outlined in Figure 1. For example, in subsections, primary, secondary and tertiary are numbered respectively S1.1, S1.2 and S1.3. In Section M, these subsections are numbered M1.1, M1.2, and M1.3

Over the years, there has been a blurring of the edges between mathematics and science education. For example, techologically based studies have drawn on both disciplines. However, we carried out separate reviews in science education and mathematics education because of the distinct bodies of literature in these areas. The proviso was that a final analysis should take into account any future research directions in the overlap between the two areas.

The reviews are being disseminated to inform others who, for one reason or another have interests in these areas of concern.

LEVEL OF SCHOOLING

AREAS OF RESEARCH	PRIMARY	SECONDARY	TERTIARY
PROVISION			
(1) AMOUNT, How much is taught?	1.1**	1.2	1.3
(2) CURRICULUM, What is taught?	2.1	2.2	2.3
(3) TEACHER EDUCATION, Who teaches?	3.1	3.2	3.3
(4) SUPPORT MECHANISMS, What systemic assistance is given?	4.1	4.2	4.3
PARTICIPATION			
(5) Who takes part in learning?	5.1	5.2	5.3
OUTCOMES			
(6) COGNITIVE, What are the knowledge based outcomes?	6.1	6.2	6.3
(7) INVESTIGATORY, What are the skill outcomes?	7.1	7.2	7.3
(8) AFFECTIVE, What are the attitudinal outcomes?	8.1	8.2	8.3
(9) TRANSITION, What are the expected and actual outcomes of students in transition from level to level?	9.1	9.2	9.3
(10) EXIT, What are the expected and actual outcomes of students in transition from school to community life (work, leisure)?	10.1	10.2	10.3

Figure 1. Review of Research Matrix

Note **: Numbering system used in Sections S (Science) and M (Mathematics)

SECTION S

Science Education Review

S1. Amount of Science Taught

S1.1 Primary

Seddon (1981) has recently examined six reviews of primary science and found that all considered the time spent on science in primary schools. Three of the six were conducted in Victoria. Unfortunately, those carried out in other states were difficult to obtain. Symington and Hawkins (1972) found that, in a sample of Melbourne teachers, 64 percent averaged between one and three hours per week and the remainder averaged less than one hour per week. Henry (1977), while studying the impact of a new course in Victoria five years after its inception, found that half the 402 teachers sampled taught less than one hour of science per week. The other half taught between one and three hours per week. More recently, Colbourne and Brockley (1981) collected information from 200 primary teachers, and found results similar to those reported by Symington and Hawkins. The population used here were those who used the Bendigo College of Education Resource Materials, hence the respondents may not represent fully primary teachers in schools across the state. An interesting trend found by Colbourne and Brockley is the incorporation of science within a General Studies program in primary schools. One quarter of the responses indicated this arrangement. Altogether, the results indicate a relatively low amount of time devoted to science related activities in primary schools in Victoria. Seddon concludes that the proportion of time spent on science at these levels has probably diminished in recent years. However there is some confusion in the findings because none of the surveys gave an indication of the time spent on other areas of the curriculum.

S1.2 Secondary

Two national studies with adequate sampling and response rates (greater than 90 percent) collected data on the amount of time devoted to science in secondary schools. Owen (1978) and Ainley (1978a) showed that, in states where there are three years of junior secondary school (years 8-10), more time was devoted to science in Western Australia than in South Australia or Queensland. In states where there are four years of junior secondary school (years 7-10), less time is devoted to science in Victoria than the other states; New South Wales, Tasmania and the ACT. More recently, Commons (1982) found that the situation in Victoria had not changed. He found that the average amount of time spent on Science in years 7-10 was almost the same figure quoted by Owen. Commons found that, in 22 per cent of schools, there were at least one group of students who would not be taught science in 1982. This time allocation, about 2.4 hours per year in Victoria, is below that recommended by the Australian Science Teachers Association who state that

> "in each year of the junior secondary school, there should be a minimum of three hours per week study of science for all students."

Concern with the amount of science taught has been heightened by the findings that amount of time on (general) science is linked to subsequent levels of enrolments in senior secondary science subjects (Ainley, 1982), on science achievement (Keeves, 1976) and interests and attitudes to science. Most research acknowledges that, in addition to quantity, the importance of the quality of science teaching must be taken into account in determining factors affecting transition numbers and levels of achievement.

As far as can be ascertained, no comparative studies of time allocated to senior school sciences has been undertaken. At this level of schooling, students make choices between subjects and the non compulsory nature of the curriculum makes the topic less contentious. However, informal evidence suggests that some schools are finding it difficult to maintain the range of science subjects offered to senior secondary students. A study of ways of solving problems associated with this reduction would be of benefit to educational planners.

S1.3 Tertiary

No published reports were located on time spent on science subjects in tertiary institutions.

S2 Curriculum

S2.0 Introduction

For this report, we shall adopt Skilbeck's (1975) paradigm to define curriculum. The paradigm consists of five elements; (i) needs assessment or situational analysis, (ii) objectives or intentions, (iii) resources, physical plant and materials, (iv) implementation, and (v) evaluation. Student outcomes can be thought of as a subset of evaluation. However, because of the degree of interest in student outcomes, they have been treated in a separate section. Nevertheless, there will be some overlap between this section and that devoted to student outcomes.

S2.1 Primary

It is apparent that there have been concerted attempts to provide curriculum guidelines for teachers in primary schools to assist them in teaching science (Newman, 1978). While it is clear that primary school science has largely developed from courses in nature study (White, 1981, Geddes, 1978) there is little doubt that large scale curriculum developments in the USA have had an influence on the present trends in state guidelines, now available in this country.

Seddon (1981) undertook a review of surveys of practice, and Pearce (1981) has carried out a useful comparative analysis of the documents relating to primary science in each state. Eight points are identified for discussion.

(i) Why is there relatively little attention given to the statement of a rationale for the inclusion of science in the primary school? Is it largely taken for granted that all -- the teacher, the student and the community -- see the desirability of primary science?

(ii) Although a number of documents mention, in their rationale or aims, the increasing impact of science and technology in our daily living, only one document puts relative importance on this content area. Is emphasis on the problems and benefits of technological change generally desirable at the primary school level?

(iii) Considerable importance is attached to the development of intellectual skills, but little emphasis is given to the development of motor skills, and social skills and attitudes, and the specific role science experiences can play in such development. Yet, an activity-based program, with its emphasis on physical handling of materials, and on group work surely provides an ideal vehicle for the development of such skills. Should more consideration be given to these areas?

(iv) The aspects of the documents showing greatest diversity of opinion are the content and sequencing of primary science programs. Is the acquisition of science process skills, and positive attitudes together with a general appreciation of the environment a sufficient outcome for primary science? Or, is there a set of fundamental concepts and underlying principles which could be slowly developed at the same time as the skills and the attitudes, through a careful use and sequencing of appropriate activities, without the loss of flexibility, variety and interest?

(v) The lack of mention of the transition from primary to secondary science is interesting and brings up a number of questions. What is the relationship between primary science education and secondary science in each State system? What do the secondary school systems expect of primary science? How do these expectations match up with the outcomes of primary science? What are the implications of the increased emphasis on discovery learning in the primary school for the teaching of science at the secondary level? Is there a way of improving the transition from primary to secondary science for both the child and the teacher?

(vi) Another point of interest arises from a consideration of the choice of activities in a program. How does a teacher reconcile the need to consider and build on the interests of children, all individuals, in the selection of science activities for both the long term and the short term? Is there really any choice for the child? Should there be? In spite of the child-oriented statements on attitudes, the general impression given by the documents is that, whereas the teacher has a wide variety of resources open to him in the choice of materials and activities, the child has very little or no choice.

(vii) In view of the general emphasis on school-based curriculum development shown in these documents, and the common lack of guidelines on evaluation of the child's progress, the course activities and the whole school program , is there a need for more information on assessment and evaluation?

(viii) Are individual guidelines based on a particular theory of education? If so, should this be stated more clearly to make the underlying theoretical framework more obvious to teachers? If not, on what is each program based?

Pearce (1981:34)

These observations would make a useful starting point for reviewing what research has been done in the area, and what research should be carried out in the future.

There is little published research available about primary science curriculum in this country. An examination of those available shows that preparation for implementation has been one problem given some study. Results consistent with experiences in the USA have been found. Studies in three states show that it is difficult for teachers to assume roles in classrooms to which they are unaccustomed, that teachers need supporting materials, and most of all, they need support personnel, particularly during the early stages of use of the new teaching strategies and materials (Crocker, 1979, Crawford, 1980; Colbourne and Brockley, 1981).

Symington is one of the few researchers who has examined teaching-learning activities. He investigated the influence of teachers' background knowledge in science on decision making in the classroom. He concluded that the extent to which teachers could suggest options for student activities was related to their background knowledge in science.

Symington (1980) has also implied that teachers find it difficult to identify investigable problems related to everyday phenomena, a task central to the implementation of most science curriculum programs. He has also shown that, when teachers introduced materials to primary school students for a period of 'free play', there was a significant increase in the number of scientific problems the students could generate. The findings suggest that teachers could structure classroom situations to achieve this without a great deal of scientific knowledge (Symington, 1978).

S2.2 Secondary

So many examples fall in this subsection that it is impossible to discuss them all. There has been great interest in secondary science curriculum development and its effects, particularly in the compulsory years of schooling, years 7-10. The creation of materials and ideas by the Australian Science Education Project (ASEP) was a significant event in this country's approach to curriculum. Not only did ASEP encourage new content and methods but it was also a national project, a rare example of state cooperation on schooling. ASEP has provided a focus for studies of school science over the past eight years and precipitated other science education research. Major evaluations by Tisher and Power (1975), Fraser (1979), Owen (1979) and Northfield (1980), among others, have enabled the impact of ASEP to be catalogued. Fraser (1977) has written an excellent summary of the findings, which relate to elements such as teacher and student outcomes, diffusion of the materials and implementation, and teacher reactions to the units.

Other studies have focussed on the impact of state level initiatives. For example McBurney (1978) carried out an extensive evaluation of the implementation of the NSW Junior Secondary Science Syllabus. In Western Australia, Dynan, Parker and Ryan (1978)

monitored the introduction of a new subject - Physical Science- into senior secondary schools. In the same state, Rennie (1981) carried out a comprehensive evaluation of a new approach to Physics through the use of Project Physics ideas and materials. In NSW, Quinlan (1981) studied the impact of Project Physics on 39 teachers and 740 HSC students. A finding, shared by many studies of curriculum change was the reluctance of teachers to change from 'traditional' teaching roles. (In an analysis of the curriculum movement in science in the USA, Welch (1979) estimates that the curriculum accounts for about five percent of the variation in student achievement. The teacher is still the most important element in the curriculum process!!)

Given the emphasis on school based curriculum development, there is surprisingly little documentation on science department curriculum decision making. Studies by Preston and McKenzie (1978) and Newlands (1979) are among those which have appeared in the literature.

The studies above have conceived a curriculum as a whole. Other research has focussed on one or perhaps the interaction of two of Skilbeck's (1975) curriculum elements. There are several studies on resources. For example, work by Ainley (1978b) and Moyle (1979) sheds light on the management of school science laboratories, and studies by Owen (1978), Tulip (1980) and McAllister (1982) provided information on the use of textual materials in the states. Goodrick (1979) developed an excellent schema in which most of the available written materials for science are reviewed. Rosen (1979) has shown that educational games were just as effective as other instructional techniques when used to aid revision of science topics.

Some extended research has focussed on what takes place in the classroom. Fraser (1979) and others have studied learning environments, and their links with enquiry based teaching. From a different

perspective, Butler (1980) and his associates are currently engaged in a large scale study of teacher and pupil behaviour in which the time students spend on task related activities is charted. There are wide variations in on-task time between classes, and between teaching strategies, which should be of great interest when linked to student achievement (Beasley and Butler, 1981: Beasley, 1982).

There are several other issues raised in the literature about classroom strategies: for example, individualisation (Theobald, 1978); slow learners (Payne, 1980); the problems of low reading ability of students and some remedies (Beeson and Fletcher,1979); and values education (Gauld, 1980).

An interesting variation in evaluating curriculum was that employed by Schibeci(1980). He asked teachers of science to report their attitudes to science and science teaching. He found that: (i) teachers regarded student enjoyment of science to be very important, but that student attitudes were rarely assessed in a systematic fashion, (ii) teachers regarded their own attitudes as an important influence, yet there was a confusion among teachers on their attitudes to science, (iii) teachers generally could not justify science as a subject in secondary schools, (iv) students perceive teachers as models of scientists, (v) the interest of students could be increased by more 'relevant' work, preferably practically orientated.

The plethora of available research on curriculum has provided ample material for reviews of a philosophic or sociological nature. For example, White (1980) examined the role of science in the curriculum, Smith (1982) reviewed developments in integrated science, and Fensham (1980) has identified two perspectives in studying curriculum change in Science in Australian secondary schools. There has been some attempt to predict future developments in science education in the 1980s, for example by Power (1980) and Fensham (1981). The former article examines chemical education, and is one of the few overview articles which focusses on science subjects offered in the upper secondary school.

S2.3 Tertiary

While there are few examples of evaluations of whole courses available in the published literature, there have been a few important contributions to the study of an aspect of curriculum, particularly laboratory work. Hegarty's (1978) framework for evaluating the level of scientific enquiry in tertiary science courses, and her subsequent assessment of courses in two New South Wales universities is an outstanding example. Her results are discussed more fully in section S7. Boud and his co-workers have extended the traditional notion of laboratory work somewhat, to include a range of innovatory teaching methods. They have reviewed these under eight headings: Keller Plan (Personalised Self Instruction), Audio-tutorial, Computer Assisted Learning (CAL),Learning Aids Laboratory, Modular Laboratory, Integrated Discipline Laboratory, Project Work and Research. This review identifies three trends:

> Firstly, there is a trend towards the individualization of laboratory teaching in the earlier days of undergraduate courses. There is much emphasis on self-teaching packages whether they be of the form of the audio-tutorial method, the Keller Plan, or other more eclectic approaches. This has enabled much of the day-to-day running of laboratory classes to be put in the hands of tutors and demonstrators leaving more senior academic staff to design and construct the learning packages that are used.
>
> Secondly, and complementary to the first tendency, project work has established a significant place in the later stages of undergraduate courses and elements of project work can also be found at all levels. Concern to bring some of the realities of laboratory practice into first degree courses has focussed on individual, and to a much lesser extent, team projects. Students work on projects whose outcomes are not known to themselves or to their superiors and thus experience some of the frustrations and insights of scientific practice.
>
> The third trend to be observed is towards the breaking down of the administrative barriers between lectures, tutorials and laboratory classes. It was difficult to classify some methods as being principally concerned with laboratory teaching at all.

> Much CAL is concerned with situations that could not be easily examined in either lectures or laboratory classes, and in the audio-tutorial, Keller Plan and Learning Aids Laboratory, the distinction between the laboratory and non-laboratory components are notional. This integrative trend seems to be a very healthy sign that the teaching of science is being seen as a unified activity not to be artificially separated into theory and practice solely for administrative convenience.
>
> (Boud, Dunn, Kennedy and Walker, 1978:91)

They also conclude that "apart from formative evaluation, laboratory teaching is an almost totally neglected area of research." Presumably, this refers to traditional laboratory activities. This conclusion reinforces the importance of Hegarty's work in this area.

Two whole course evaluations were found in the literature. Carras and Mainsbridge (1979) carried out an action research study on a program designed to improve the performance of physical science students with deficient secondary school backgrounds in the sciences and mathematics. The study, at Murdoch University, showed that the program was supportive of students in terms of their academic performance in the first year, and that their two year retention rate was comparable to the university norm.

Hirst, Malcolm and Owen (1980) evaluated an innovative approach to teaching first year tertiary physics, by comparing performance and attitudinal outcomes of those students in the new program with those studying a 'traditional' course. The 'experimental' group outperformed those in the traditional program on cognitive outcomes despite having lower average HSC scores in science and maths. The innovatory program emphasised the relevance of physics to everyday life, and through the program, student personal skills were emphasised. Results on the attitudinal scales verified that students in the new program perceived the objectives of the course.

The dearth of published work in this area has already been referred to. It is likely that much "in house" course evaluation is taking place. Tertiary science teachers could gain much from sharing with others their approaches to planning, implementing and evaluating courses. Among other outcomes, increased knowledge of tertiary science progress, such as that reported by Carras and Mainsbridge, could do much to improve course guidance to students making the transition from secondary to tertiary studies.

S3 Teacher Education in Science

S3.0 Introduction

During the past two decades, some attention has focussed on the identification of the characteristics of the 'ideal science teacher'. Opening the Annual Conference of the South Australian Science Teachers Association in 1975, Greg Ramsey presented several important perspectives of schooling as they applied particularly to science education in this country. When discussing professionalism, he suggested that an effective science teacher:

(i) Is well educated in science and the liberal arts,

(ii) Possesses a functional philosophy of education and technical skills of teaching,

(iii) Continues to grow in knowledge and skill through his career,

(iv) Insists on a sound educational environment in which to work,

(v) Maintains his professional status,

(vi) Contributes to the improvement of science teaching, and

(vii) Takes a vital interest in the quality of future science teachers.

(Ramsey, 1976:3)

It is apparent that Ramsey places strong emphasis on the affective or attitudinal aspects of teacher behaviour.

In an American study, Simpson and Brown (1977) surveyed groups representing: high school science teachers, science supervisors (inspectors), school principals and college and university science educators. Using a technique of progressive focussing on outcomes (the delphi technique), the researchers sought to gain a consensus on what should be the basic competencies of science teachers entering the profesison. Using a statistical technique known as factor analysis, seven fundamental areas of skills were uncovered. These were:

Fundamental Skill Area	Example of a Competency Statement
Products and Processes	Be able to define science and discuss intelligently the process and values associated with scientific endeavours
Professional Knowledge and Attitudes	Be committed to the teaching of science and the corresponding roles which are inescapably associated with such commitments.
Human Relations Skills	Be able to establish and maintain rapport with students.
Planning Skills	Be able to design assignments which will provide for successful learning opportunities to groups of pupils with varied abilities and interests.
InstructionalSkills	Be able to provide students with concrete, "hands-on" experiences that will lead to concept foundation.
Management Skills	Be capable of properly storing and maintaining science material and equipment.
Evaluation Skills	Be able to evaluate classroom behaviour or to secure such evaluation from others in order to make any appropriate changes in behaviour.

(Simpson and Brown, 1977:217)

An interesting result of this classification is the emphasis given to the last four items; items which are fundamental to curriculum development as outlined by Skilbeck (1975) in his important paper on school based responsibility for the curriculum.

Bybee (1978), also in the USA, used a progressive focussing method called 'Q sort' in order to obtain a ranking of teacher skills thought to be important in the work of the professional science teacher. The original lists of skills were derived from members of the Association for the Education of Teachers in Science (AETS). The rank order of skills required was:

(i) Adequate personal relations with students,
(ii) Enthusiasm in working with students,
(iii) Adequate teaching methods and class procedures,
(iv) Knowledge of subject matter, and
(v) Adequate planning and organisation.

Commenting on the preservice education of Australian science teachers, Light (1979) believes that they need a basic training in the pure sciences, complemented by appropriate professional studies. Preservice studies in this area should emphasise the acquisition of classroom skills and techniques. In addition, beginning teachers must understand notions of curriculum development.

From what has been written it is possible to identify the characteristics of the 'ideal' science teacher in broad terms. He (she) must be a person who is skilled in the knowledge of science concepts and have an understanding of the nature of science. He should: be able to develop effective curricula; be familiar with behaviour patterns of students; be highly motivated and have certain personal characteristics related to maturity and confidence as a human being. As Zoller and Watson (1974) have commented:

> "It is quite clear that prospective science teachers are expected to be admirable persons: wise, thoughtful, humane, mature, socially oriented and educated."

A key question for us is whether such 'superbeings' (Rosen, 1976) can be produced from our courses, and whether the present structure of programs being offered can help develop the characteristics of an effective science teacher which have been outlined in this discussion.

Despite extensive deliberations about the outcomes of pre-service courses, there is little Australian literature about how courses in action are conducted, or how they affect prospective science teachers. The few recent reports available are reviewed below.

S3.1 Primary

Most studies which fall into this category examine an element of a general teacher education course which involves College science courses. Khan (1980) used an audio tutorial approach to improve the knowledge of science of trainees at Goulburne CAE. Other studies also focussed on the problem of students' background knowledge in science. Ginn and Foster (1978), and Dooley and Lucas (1981) have both carried out investigations which suggest that an integration of science content with curriculum issues, including ways of implementing science in schools, has had a significant impact on trainees.

A more general evaluation of a primary education program was reported by Dawes and Ticehurst (1978). Beginning teachers in NSW reported that they enjoyed their new job, but felt that their College course could have given them more exposure to problems of motivation

and discipline. For science, organisational arrangements in schools were perceived as significant barriers to the implementation of the discovery approach which had been encouraged during teacher education.

S3.2 Secondary

Beasley (1981) examined the perceptions of students in the Diploma in Education course at the University of Queensland, and mapped their change in competencies. Overall, performance improved throughout the year, but at the conclusion of the course, many students had not mastered competencies viewed as essential by science subject masters. An interesting conclusion is that teaching rounds were perceived to have had only a small effect on the attainment of the competencies. The problems of induction have been mentioned earlier. Betjeman et al. (1979) argue for greater effort to be made to assist beginning teachers in evaluating their performance when posted to schools. Support systems at the school are seen to be essential for beginning teachers.

S3.3 In Service Education

There is little argument that teacher education does not stop at the preservice phase. Over the past decade, the availability of Federal funds for inservice programs has led to an increase in participation of teachers in inservice courses. However, there is little documentation available on the needs of practising science teachers, or their involvement in inservice courses. Fawns (1981) has presented data on a Victorian effort to improve secondary school curriculum decision making in science, which has evidently fulfilled a need. This study is a rare example of an evaluation of such a program. Overall, one suspects that the major effort in teacher education is in the development of programs, rather than in their evaluation.

S4 Support for Curriculum Development

S4.0 Introduction

Over the past decade, teachers and schools have been granted far more responsibility than before for the total school curriculum. There is little doubt that the move towards school based curriculum development(SBCD) has been a notable event in recent Australian educational history. Proponents of SBCD argue that involvement in decision making makes for greater staff commitment to the program and assists in its implementation. It is also claimed that local decision making is necessary to account for the unique requirements of students attending a given school, and that those who understand these requirements are in the best position to design the total educational program.

In this context, those working at the system level are beginning to adjust to the needs of SBCD. The key questions are: (i) do schools and teachers require assistance from those based outside the school to plan and implement science programs, and (ii) if so, what is the nature of this assistance?

S4.1 Primary

There is evidence that teachers of primary school science require help in implementing coherent science programs. Crocker (1979) studied the implementation of a new science curriculum in Queensland. His report cast doubt on the ability of principals and teachers to introduce the program without external assistance, because of lack of expertise in the school. Principals and teachers wanted a high level of prescription. Where science classes were observed, teachers tended to dominate proceedings, which was at variance with the intentions of the project developers.

In Victoria, Colbourne and Brockley (1981) report that teachers, if supplied with structured materials, are more likely to include science in the curriculum. It was also found that most teachers had received little or no inservice training in science; 78 percent had undergone one day or less in the past four years.

S4.2 Secondary

Data here reflects a similar problem amongst secondary teachers. Kee (1982) has found a need among Victorian Science Teachers for information about resources, course documentation and evaluation among other matters.

In a national study, Owen (1978a) examined factors which promoted the development of school based science curriculum programs which took into account recent developments in science education. This study and associated research overseas, suggests that the effective implementation of modern programs depends on three groups of factors:

(i) characteristics of any new materials to be used; their explicitness and complexity,

(ii) strategies for assisting schools; inservice training, feedback to schools, on site visits to assist implementation, and

(iii) characteristics of the adopting schools; support of the principal, the innovation climate amongst the adopting teachers.

An atmosphere of mutual cooperation between those in schools and support personnel, such as consultants seems to be essential for effective external support for SBCD.

There appears to be a genuine need for system level support in secondary schools. The evidence suggests that:

(i) available information must be of a certain quality in terms of its relevance, applicability and understandability,

(ii) the approach by external disseminators must be person intensive, interactive and continuous, and

(iii) educational settings, at state, regional and school based must come to possess the characteristics of administrative support, peer interaction and problem solving orientation (Owen, 1982).

S5 Participation in Science

S5.1 Primary

As indicated earlier, there is some evidence that a sizeable proportion, perhaps 50 percent of primary school pupils in Victoria do not take part in any form of science education. There are few other figures available. However, it is known that there is variation in emphasis given to supporting science in primary schools between states. Studies by Colbourne and Brockley (1981), in Victoria and Crocker (1979) in Queensland have pointed to difficulties in course implementation at this level which relate to participation. They should provide guidelines for further study in this area.

S5.2 Secondary

Ainley (1978a) provided relevant comparative data about participation in year 7-10 science classes. From a 1975 survey he concluded that not all secondary school students were students of science. While in years 7 and 8 nearly all Australian secondary students took science, by years 9 and 10 some had dropped the subject completely. There was considerable variation between states. For example, whereas all students in Western Australia and New South Wales took science in year 10, one quarter of Queensland's students at this level did not take a science subject. Differences were also noted between school systems. There was a larger proportion of non-science students in Government schools than in Catholic or Independent schools.

Ainley notes that the students who studied no science were mainly girls. About half of the girls in year 9 and 10 in Queensland studied no science at all. The girls who did not take science were following a course of commercial studies for which science "appears to have been considered inappropriate" (Ainley, 1978a:136).

Ainley also examined senior school participation rates in science subjects. He developed a Science Enrolment Index (SEI); the number of total subject enrolments in year 12 divided by total HSC enrolments. The SEI varied between states, and also between school systems. It was highest in Western Australia and lowest in Victoria. It was higher in every state in non-Catholic Independent schools than in Government schools. The SEI was lower again in Catholic schools in all states except Victoria.

Another way of looking at enrolment trends is to consider the percentage of a group or cohort starting secondary school which goes on to study science subjects at HSC. For Physics in Victoria this value fell from 10.2 percent in 1969 to 7.9 percent in 1977, then rose to 8.0 percent in 1979. This was the lowest value in any Australian state. Figures for the other states ranged from 10.8 percent in Queensland to 12.9 percent in Western Australia (Lofts, 1981).

Dekkers and his associates have analysed enrolment trends in the traditional year 12 science subjects; Chemistry, Physics, Geology and Biology. They have found, for example, that Geology enrolments are low considering Australia's involvement in mineral exploration. While 571 students enrolled in year 12 Geology in Queensland in 1979, only 114 enrolled in Western Australia. The percentage of the cohort going on to year 12 Geology from year 8 varied from 0.4 percent in Victoria, to 6.1 percent in South Australia. These figures were derived from statistics presented by de Laeter and Dekkers (1982) who provideda similar analysis of trends in biology enrolments (de Lacter and Dekkers, 1981). The percentage of year 8 cohort proceeding to a biology enrolment in year 12 varied from 32.7 percent in Western Australia to 14.6 percent in Victoria. The actual numbers of Biology enrolments in year 12 in 1979 varied from 15100 in New South Wales to 2320 in Tasmania.

Other studies have concentrated on trends within states. In Western Australia Carras and Jennings (1979) examined enrolment patterns at senior secondary school and tertiary level in the sciences.

They conclude that, while physical science enrolments have been static or turned down slightly, enrolments in mathematics and biology have risen quickly at both levels. They report that tertiary science enrolments have continued to rise at a rate comparable to other major faculties at the University of Western Australia. These trends are associated with two factors: (i) the relatively difficult nature of senior secondary school Physics and Chemistry, and (ii) perceived employment opportunities for graduates of the various tertiary science major studies. It should be noted that, in respect to the first point that Western Australia is one of the states to encourage enrolments in alternative approaches to physics (Rennie, 1978) and through new subjects such as Physical Science (Dynan, Parker and Ryan, 1978). These factors could also relate to the generally high levels of student involvement of students in senior school science in Western Australia.

In Victoria, Walsh(1979) analysed trends in science and mathematics enrolments in senior secondary schools. Amongst males in government schools and in non government schools, the traditional 'two sciences - two mathematics' combination remained the most prevalent, accounting for about one quarter of all enrolment patterns at year 11. At year 12 however, a smaller proportion of males in non government schools attempted the traditional combination than did their peers in government schools (16 percent versus 26 percent in 1977). In general, girls attempted fewer maths and science subjects at these year levels. Whilst more science and maths were taken in non-government schools by girls at year 11, the patterns at year 12 were remarkably similar in both systems. An unfortunate aspect of Walsh's work is that he has not distinguished between Catholic and other Independent schools. Ainley's data shows clearly that the level of facilities differ in these two systems. For this reason alone, one might expect differences in participation in science between these systems.

One of the recurring themes in these analyses is the relatively small numbers of girls attempting science subjects at senior secondary school. Ingvarson and Jones (1981) have carried out a review of

sexism in science. They suggest that women need to study science to ensure that: (i) both sexes are represented in power groups, (ii) personal and national potential of the total population is utilized, (iii) women understand technological change and the intellectual processes which constitute science, and (iv) career options are not reduced. The paper contains a brief review of evidence of discrimination against women in science, and suggests that schools have a key role to play in encouraging students to study science and enter science based careers.

S6 Knowledge Outcomes

S6.0 Introduction

Several trends can be discerned in studies of the performance of students on cognitive tasks related to science. Most can be linked to developments in the individual (maturation, etc), or to the effects of curriculum and instruction (teaching processes), or to the interaction between these two elements.

S6.1 Primary

There were very few studies of cognitive outcomes among primary school students in science. Seddon (1981) does not consider outcomes of this nature in the discussion of recent reviews in this area. The lack of comparative data on science cognitive achievement is probably linked to factors such as the variations between states in the prescription given to schools about science studies, the general thrust of the available guidelines, the degree to which science is incorporated into the curriculum, and the emphasis placed on the range of possible outcomes. At a more fundamental level, the question must be raised as to the extent of importance which should be placed on cognitive outcomes at this level.

The general approach to science in the curricula has been to encourage enquiry and to stimulate interest and enjoyment of science, and there is some evidence that teachers are succeeding in this regard (Power, 1979). As an example of outcomes, material designed to be used in science in the United Kingdom, and adopted to some extent in Australia, focusses on development of attributes such as curiosity, originality and perseverance. There is, however, an acknowledgement that teachers could look for attainment of key concepts at the upper levels of the primary school, such as volume, force, energy, change,

and adaptation (Harlen, 1978). Recent curriculum work in at least one state (Queensland) also focusses on student attainment of these and other concepts.

S6.2 Secondary

One group of studies has concentrated on conceptualising the role of memory as a mediating factor between instruction and performance. This has resulted in the postulation of four types of memory structure: propositions (verbal), intellectual skills, images and episodes. Memory has also been seen to be a system having several components: a transient store, intermediate storage and processing, and long term store (White, 1977). White and his co-workers propose that the way material is organised and presented determines the ability of the memory system to store and use the information. Using these ideas, for example, Kellett (1979) has proposed methods of teaching which will facilitate the understanding of learners with limited memory capacities.

Another perspective on student performance is through the Piagetian approach. Blake (1978) has carefully mapped stages of intellectual development of adolescents. Also, through a series of case studies, he suggests that many of the intellectual tasks expected of students through existing curricula may be too difficult. One exception seems to be the ASEP materials which, according to Dawson and Rowell (1981), are so well arranged that they promote understanding in a range of teaching situations. However, they suggest that additional structuring of the materials by teachers can facilitate the performance by teachers (see also Tisher and Power, 1975).

A third element of interest is the role of language in the learning of science concepts. Lynch (1978, 1979, 1980) has carried out some extensive work on concept recognition across year levels in Tasmanian secondary schools. He has found, for example, that the recognition of concept definitions (RCD) is not the same as language,

that RCD's are acquired at different rates over the years 7-10, that IQ, year level, age, socioeconomic status and sex in that order all produce differences in RCD scores and that even gifted children have difficulties with distinctions between concepts such as atom/molecule, solid/liquid, and mass/weight. He concludes that variations in teaching quality also affect student understanding of science concepts. Other important work on the more general role of language in students understanding of science has been carried out by Gardner (1972, 1975, 1978). In common with most other subject learning, the role of language use by teachers and in textual materials has a significant effect on student understanding.

A relatively new approach to understanding student problems with learning science has been fostered through the Learning in Science Project, carried out in New Zealand by Osborne and his co-workers. The study has focussed on students thinking and understandings and data was collected by interview and observations of classroom situations. Some of the results are disturbing to science educators. For example, Tasker (1981) observed groups of 11-14 year olds in typical science lessons. The major aim was to establish what children say, do and think about while they carry out experimental observations. He found that (i) a series of lessons were perceived by students as isolated events while teachers believed them to be related experiences, (ii) there was a marked difference between the purpose, nature and significance of a set task between students on one hand, and teachers on the other, and (iii) students lacked assumed pre-requisite knowledge. As part of a major summary of the project, Osborne (1981) reports on the problems children have in learning science because their views of the world and word meanings are largely unrecognised by teachers and curriculum developers:

> "If science is finding out about things of the natural and technological worlds and about how and why things behave as they do, then all young children as well as scientists engage in this activity. Unfortunately the views children develop (we call this children's science) based on everyday experiences can

be quite different from the consensus scientist's view (scientist's science based on 400 years of intellectual endeavour and contrived experimental situations). This leads us to ask ourselves whether in teaching science we wish to:

(i) reshape or change the pupil's view to make it more scientific,

(ii) simply give pupils an appreciation that there is another view different to their own, or

(iii) leave the child's view undisturbed and just give him/her interesting experiences?

It also leads us to ask, do we as teachers need to know:

(a) the likely views of pupils before teaching, even if those views are quite non-scientific;

(b) the consensus view of scientists; and

(c) where our own views, as teachers, lie with respect to the above views?

Finally, at what age should we start teaching particular scientific ideas? It has become fashionable in recent years to suggest that if children have difficulty in grasping an idea then it must be too difficult and should be delayed until pupils have reached a suitable level of intellectual development. It could be argued that if children have ideas from a young age, some of these ideas may be more difficult to modify at a later age than at an earlier age when the ideas are possibly less ingrained. Perhaps it is easier to teach the biological concept of animal to five year olds rather than twelve year olds? Experimental learning with air tracks at age six may be the opportune time for some children to begin to develop a Newtonian rather than an Aristolelian view of mechanics. (Osborne, 1981:7)

Despite the emphasis on enquiry approaches to science, there has been a renewed interest in more teacher centred methods over the past few years. A paper by Novak (1981) has drawn together some key developments in the teaching of concepts. Some Australian research, such as that by Gunstone and White (1980) suggests that more emphasis should be placed on teaching strategies designed to promote the acquisition of concepts by secondary schools science students. Recent

work, in the USA, by Joyce and Showers (1981) and others implies that, when teachers learn certain routines and put them into action in the classroom, student understanding of concepts is considerably enhanced. Whilst these routines incorporate the role of strategies such as teacher questioning and pausing, the routines are rather more complex and integrated, involving certain logical moves involving teachers, materials and students. A difficulty is that teachers need support in learning the routines, and more American studies are proceeding in this respect. However, the work being done seems to have considerable promise. It is interesting to note that Beeson (1978) persuaded a group of Australian teachers to use one of the routines in teaching a science unit, based on Ausubel's work on advanced organisers. Despite the fact that teachers showed no strong preference for the approach, it was subsequently shown that student outcomes were enhanced, compared to student outcomes from other teaching strategies.

Difficulties in concept attainment is a recurring theme in the research on learning in science. An associated problem has been to develop reliable and valid assessment instruments to evaluate such attainment. A Western Australia study by Rennie (1981) has suggested that year 12 physics students distinguish between learning physics to pass exams, and understanding what physics is about. Many students apparently selected the former approach to studying physics, in order to pass the requirements of the final year certificate. It seems that it is still possible to jump academic hurdles without being required to understand key underlying concepts which are fundamental to the subject discipline.

S7 Investigatory Skills

S7.1 Primary

Despite the emphasis on activities in most current science curriculum policy statements, little was found on student outcomes associated with investigation. Indeed Seddon's (1981) review of other studies of primary science suggested that there was a marked emphasis on passive and teacher directed learning by the child.

S7. 2 Secondary

Three types of research are outlined in this section. The first is basic research on students' mental processing in learning practical skills. The second relates to the links between science facilities and student outcomes. The third concentrates on performance of students in practical skills.

As indicated previously, White (1979), in conjunction with Gagne, has developed some elegant approaches to help us understand the role of memory in the learning process. They classify memory into four categories: verbal, intellectual, imagery and episodic. Of these, images and episodes are seen to relate to the performance of practical skills. Some work by Beasley (1978a) suggests that 'mental practice', a cognitive input, can assist students perform laboratory skills.

Attention has been given to research on practical work in secondary schools. A national study by Ainley (1978a) examined the impact of the Federally funded Australian Science Facilities Program (SFP) through which $123 million was spent on laboratories from 1963. Ainley found that as a result of the SFP: (i) accommodation for science classes was substantially improved; by 1975 most science was being taught in laboratories, (ii) conditions were generally better in non Government

than in Government schools, (iii) the availability of apparatus was no longer a serious impediment to practical work, and (iv) laboratory assistants (not funded by SFP) were an important element in the use of laboratories. Better facilities were associated with an enriched learning environment and more active forms of science learning. Students reported more emphasis on experimental work and less on the use of textbooks, and greater encouragement to explore scientific problems. The facilities also encouraged different kinds of teaching, reducing the percentage of expository teaching.

We now turn to the development of ideas of assistance to teachers in measuring the outcomes of enquiry oriented science. Secondary school students prefer being involved in activities to more sedentary classroom approaches (Dekkers, 1978; Fraser, 1978, Dawson and Bennett, 1981). Teachers appear to have evolved a hierarchy of appropriate skills and expectations from enquiry centred lessons, according to Lynch and Ndyetabura (1982). They found that, at years 7 and 8, skill techniques and observation were seen as important to teachers, whilst more complex skills, such as interpretation of data, were more important at year 12.

Compared to the efforts made to construct appropriate tests of cognitive objectives, assessment techniques to measure laboratory skills are lacking, according to Beasley (1978b). Hence the recent work of Beasley (1982) and Giddings and Hofstein (1980) are valuable as guidelines for the creation of appropriate assessment techniques for teachers in this area.

From the summary, it can be seen that studies of practically based skills have concentrated on the secondary school. We found virtually no work on skill acquisition amongst young pupils at primary schools. Either researchers in Australia have not addressed the problem, or there is little science taught in primary schools, or both.

S7.3 Tertiary

Hegarty's (1978) work on laboratory work in tertiary institutions contains excellent guidelines for analysing the emphasis on student activities in tertiary level science courses. McDonell (1978) has shown that measurement procedures and experimental design are important objectives for first year physics practical work, and Dunn, Kennedy and Boud (1980) have listed important scientific skills required of graduates. However, there was litle found in the literature which linked the acquisition of scientific practical skills to the objectives of courses in science in tertiary institutions.

S8 Affective Outcomes

While there has been an emphasis on cognitive outcomes in science teaching, the importance of affective measures has also been acknowledged. A distinction has been made between attitudes toward science (e.g. interest in science, attitudes toward scientists, attitudes toward social issues by scientists) and scientific attitudes (honesty, curiosity, suspension of judgement). Gardner (1975) has carried out a review of attitudes to science. He concludes that: (i) correlations between attitudes to science and achievement are generally low across periods of compulsory schooling, but tend to increase toward the end of secondary school, (ii) students favourably inclined to science tend to be: serious, achievement oriented, realistic; and independent, conventional and conformist, (iii) boys have a greater interest in science than girls (iv) attitudes to science relate to teachers' use of discovery methods and group work, (v) a cluster of home background variables associated with parental interest in science affect the attitudes of young children towards science, (vi) most curriculum efforts to change students attitudes are small, indeed they tend to be negative. The extensive research in physics education shows this trend most graphically (Mackay, 1971), even when non traditional approaches to physics have been adopted (Rennie, 1978).

Gardner suggests several areas of research on attitudes to science. For example, what teaching behaviours favourably affect pupils? Is student success related to attitudes? Do external examinations have a restrictive effect on teachers and pupils? A wider question is: do schools exert an influence on transmitting existing societal sex roles to science students?

Gauld and Hukins (1980) reviewed studies of scientific attitudes. Relations between scientific attitudes and other variables is clouded by confounding results across different studies. There is a general finding, however, that school courses which emphasise the development of scientific attitudes has affected students in the

direction expected. Sex has been shown not to be linked to curiosity, openmindedness or objectivity, but related to superstitious beliefs and attitudes to astrology.

Most of the studies in these two areas have been undertaken at primary and secondary levels. The few tertiary level studies have mostly involved changes in students' attitudes as a result of exposure to a course, generally of short duration. These studies show that changes in attitudes to science are generally small. At this level, changes in attitudes to teaching science are of concern in teacher education courses. There is some evidence which suggests that careful curriculum development at tertiary levels can improve students attitudes, particularly when the curriculum reflects the way beginning teachers might be expected to operate in schools (Ginn and Foster, 1978; Flanagan, 1978; Dooley and Lucas, 1981).

S9 Transition to Higher Levels of Schooling

9.1 Primary - Secondary

Transition effects can be divided into four areas, according to Skamp (1980). These are related to (i) the school administration, (ii) the curriculum, (iii) classroom environment, and (iv) teacher characteristics. Skamp suggests that, of these, the most serious problems in transition derive from lack of coordination across the curriculum. Williamson (1981) implies that the creation of useful guidelines for primary science teaching is an essential step in improving the transition process. If implemented, this would ensure a better grounding for students and a more uniform set of outcomes amongst students. Williamson recommends increased liaison between primary and secondary science teachers, including sharing of equipment, materials and staff time. He notes that many of the Science curriculum materials made available to secondary schools could form the basis of science programs in the final year of primary school.

Power (1979) examined the transition of a group of students in Brisbane schools, and found that there were no major problems confronting students in transition, so far as science was concerned. Enjoyment of science at school remained high, and did not drop off during the first year of secondary school. These outcomes were related to the use of appropriate curriculum materials, such as ASEP, and the interpersonal relationship between students and teachers. However, no one environmental arrangement (curriculum/teacher) was identified as superior in establishing successful transition than any other.

Dawson and Bennet (1981) shed some light on the interests of beginning secondary science students. They showed that boys and girls have different pattern of interests in topics, but similar interests

in teaching methods. Overall, topics of interest include studies of animals, human reproduction, simple experiments in chemistry, and the cause of heart attacks!! The most preferred methods were: excursions, doing experiments, watching films and making models.

Within the context of cognitive development, there has been some work done to map the capabilities of Australian students. The work of Blake (1977) has shown that the vast majority (80 percent) of year 7 students are at the concrete level of Piagetian development.

ASEP recommended that teachers use reading and cognitive development tests to determine the readiness levels of students. These resources are not readily available to teachers. The creation and evaluation of simple but valid materials to achieve this would seem to be of great value in the transition from primary to secondary levels, and on either side of this transition interface.

There is a dearth of studies on transition from junior high school to senior high school (at year 10). This is a key transition in terms of moving from a period of general education to one in which specialization occurs. An interesting question is what factors affect the decision to go on with science subjects? and what assumptions, if any, are made by teachers of year 11 sciences about the science curriculum in the compulsory years of schooling?

S9.2 Secondary - Tertiary

Two criteria used to study transition at this level are (i) acceptance of a place in a tertiary institution, (ii) success in a tertiary course, generally at the first year.

In Victoria, Elsworth et al. (1982) carried out a comprehensive study of transition from school to higher study. Among other findings, it was established that the proportion of students passing and gaining higher grades in HSC are generally greater in science subjects. This study showed that science students are likely to be advantaged over others in transition to higher education. Through their higher aggregate HSC score, science students were less likely to decline and defer offers than others.

At the University of New South Wales, Burchett and Mason (1979) examined the relationship between HSC aggregate and science performance in the School of Life Sciences for the 1977 and 1978 intakes. It was found that the aggregates under the new HSC scheme remained a reasonable predictor of success. Students who took 4 HSC units of science were better prepared for tertiary science than those who took 2 units. Multi-strand was found to be the best 4-unit science for students. The researchers suggest that students entering year 11 should note the advice of the NSW Board of Senior School Studies to choose courses in line with interests and purposes, rather than apparent abilities at the end of junior high school.

At the University of Queensland Chemistry Department, grades of first year students correlated 0.34 with tertiary entrance scores (Appleton and Angus, 1979). This was viewed as low. It is important, when examining such correlations to check the extent of consistency of aims and methods for the courses at the two levels. Although the predictive ability might be low, and thus of little use to tertiary planners, the low correlations may not be logically inconsistent if the objectives of the two programs differ.

S10 Transition from Study to Work

S10.1 Introduction

The few published school to work transition studies are associated with one of two decision points; upper school to work or graduation from a tertiary institution to work.

S10.2 School - Work

In the former area, some early studies were carried out at ACER by Keeves and Schrom (1977) and Lewis (1978). The data they analysed were collected from students who were at school in 1970. Lewis found that, in the early 1970s, few of the year 12 cohort had difficulty in getting jobs, and that most retained a job over the first year of leaving school. Obtaining a job seemed not to be associated with success in science at year 12. Lewis suggests further work on this form of transition and, given the changes in conditions in the workplace, this seems justifiable.

More recently, Sleet and Stern (1980) collected data from a sample of year 11 students in NSW. Career selection was a key factor in the thinking of students who took more than one science subject. They were mindful of HSC results in achieving career goals but were less conscious of links between employment prospects and financial rewards and the science skills acquired through studies at school.

Emmet (1981) in Victoria and Lowrey (1981) in South Australia have outlined moves in these two states designed to improve work skills of school leavers. The approaches suggested have been to develop career choice through the total curriculum rather than as a distinct part of it, a position supported by Trebilco(1980).

Regarding graduation from tertiary institutions Dunn, Kennedy and Boud (1980) asked practising scientists to nominate important general and practical skills expected from science graduates. An analysis of scientists responses showed that those perceived as needing more attention during tertiary study were: report writing, searching literature and written communication. Graduates were also polled. They believed that more time should be spent on communication skills including written presentations, practical skills including designing experimental procedures, selecting experimental procedures and designing apparatus for a specific experiment. Hegarty's (1978) analysis of practical work at the tertiary level showed that only small proportions of total laboratory time was spent on these procedures. She recommends her analytical scheme as a means by which tertiary curriculum planners in the sciences could rationalise their practical work programs.

Given the volatility of the labour market, a further analysis of the science skills required of leavers should be of value to schools and to employers. As can be seen from this section of the review, almost nothing is known about the skills required of students who leave school before year 12. How do science curricula in schools cater for the needs of these students? Are there any paragon cases of curricula which have been developed to cater specifically for the needs of this group?

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SECTION M

Mathematics Education Review

M1 Amount of Mathematics Taught

M1.1 Primary

Mathematics is a core subject in the primary curriculum, and generally also in the curriculum of the junior secondary school. All children are exposed to mathematical concepts and skills, particularly related to number work, during their first 9 or 10 years of schooling. For this reason, researchers have not usually collected information on the amount of mathematics taught, it being assumed that a lot of it is taught and that this is a very good thing.

The one exception to this is the research conducted by Rosier (1980) whose main task was to provide empirical data about mathematics achievement of secondary students in Australia in 1964 and 1978. In addition, the studies analysed the mathematics curriculum and other aspects of the educational system in order to demonstrate how differences in performance between the 1964 and 1978 groups were linked to changes in the curriculum and the system. Data collected included class time in hours per week spent on mathematics by year level for years 1 to 9 in each state. The mean number of hours spent on mathematics in primary school per week is shown in Table 1:

	ACT	NSW	VIC	QLD	SA	WA	TAS
1964	3.2	3.2	3.7	5.0	4.1	3.0	3.8
1978	3.2	3.6	3.9	5.0	3.8	3.6	3.8
% increase	0	10	7	0	-8	21	0

Table 1. Mean time spent on Primary Mathematics, 1964 and 1978. (Average time over all year levels.)

With the exception of South Australia, time spent on mathematics has remained steady or increased over the 16 year period. A number of cautions need to be made about this conclusion, however. First, these were estimates supplied by officers of the State Education Departments and applied only to government schools. Individual schools will certainly have varied from these estimates. Second, it is not clear on what basis the state officers made their estimates. Most states showed an increase of hours from year 1 to year 6 or 7. For example, in the ACT, it was 2.0 hours in year 1 and 4.3 hours in year 7; but Queensland reported 5.0 hours at each year level from 1 to 7. Third, there is a suggestion from some mathematics educators that there exists a significant proportion of primary teachers who dislike mathematics and dislike teaching the subject. Consequently they spend rather less time in the area than many of their colleagues and less than they might publicly admit.

M1.2 Secondary

As suggested in M1.1, it can be reasonably assumed that all children study mathematics at least to year 9. From then on, students begin to choose from a range of options including formal mathematics, vocational mathematics, commercial arithmetic and remedial mathematics (usually arithmetic). Again, no firm data is presented in the literature other than that supplied by Rosier (1980). The mean number of hours spent on mathematics in the junior secondary school per week is shown in Table 2.

	ACT	NSW	VIC	QLD	SA	WA	TAS
1964	4.4	4.4	4.7	5.0	4.6	4.7	4.0
1978	3.5	3.8	4.0	3.6	4.2	4.0	3.5
% increase	-20	-13	-15	-27	-9	-14	-12

Table 2. Mean time spent on Junior Secondary Mathematics, 1964 and 1978. (Average time over year levels to year 9.)

The time spent on mathematics has shown a marked downturn in the junior secondary school right across Australia during the 14 year period. Unlike the data for the primary area, these figures can be assumed to be fairly accurate since mathematics is firmly timetabled each week and it is therefore much easier to determine how many hours it occupies. As Rosier pointed out, the decrease in time allocated to mathematics in the junior secondary school should have a serious effect on mathematics achievement of 13-year-old students, one of the groups under study.

No studies appear to have been made of time allocated to senior school mathematics, presumably because of the non compulsory nature of the curriculum at these levels and the wide range of courses available. However, Rosier's study indicated a decrease in the amount of time spent on 'traditional' year 12 mathematics from 1964 to 1978 in New South Wales, Victoria and Queensland and an increase in Western Australia and Tasmania as indicated in Table 3. (No data was available from South Australia or the Australian Capital Territory for 1964.)

	NSW	VIC	QLD	WA	TAS
1964	6.5	6.7	6.8	4.7	5.0
1978	4.7	5.4	5.5	5.1	5.3

Table 3. Mean time spent on Year 12 Mathematics, 1964 and 1968.

M1.3 Tertiary

Bunder (1982) looked at the numbers of Doctoral, Masters and Honours graduates in Mathematics at various Australian universities over the period 1976-1978. Bajpai (1980) presented some data on the percentage of time spent on mathematics in Engineering courses at Australian universities and colleges of advanced education. No other reports were located on the time spent on mathematics subjects in tertiary institutions.

M2 Curriculum

M2.0 Introduction

There have been substantial changes in school mathematics curricula over the last twenty years, partly as a reaction to overseas developments. In addition, there has been a move towards school based curriculum development, especially at the secondary level. This is particularly strong in South Australia and Victoria. Blakers (1978) gives a good overview of the changes to that date, noting that:

> None of the Australian educational systems has adopted, intact, any of the reform programs produced overseas.

However, different systems were at least heavily influenced by overseas projects, such as Nuffield and SMP from the United Kingdom and SMSG and UICSM from the USA. These in turn reflect in different ways the "new mathematics" of the 1960s, a movement that has been the subject of debate over recent years. McQualter (1980) points out that it was the result of:

> (i) a growing dissatisfaction with the then current school mathematics curriculum;
> (ii) the increasing use of mathematics by all sections of society.
>
> After a period of intense activity in developing new mathematics programmes, the mathematics education community overseas has begun to review and evaluate what has happened.

That mathematics should be a compulsory area of the (primary and secondary) curriculum is little disputed, though what should be taught, how it should be taught and how it should be evaluated is the subject of continuing debate, unfortunately not always rational or considered. However, there have been a number of recent reports, whose quality has enhanced the level of debate and whose recommendations for the future require careful consideration.

The 1975 report "Overview and Analysis of School Mathematics Grades K-12" of the Conference Board of the Mathematical Sciences, National Advisory Committee on Mathematical Education (known as the NACOME report) gives a comprehensive analysis of school mathematics in the USA. Many of its perspectives and recommendations are relevant to mathematics education in a global sense. Perhaps the major recommendation of NACOME relates to a quality education:

> Those who are concerned about the education of young people must reaffirm their commitment to full, comprehensive mathematics education for all youngsters...
>
> Implications:
>
> (a) that every child is entitled to the mathematical competencies necessary for daily living in today's civilization, but the concept of "basic skills" essential to the consumer and the citizen be defined to include more than computational skill...;
> (b) that minimum skills cannot be allowed to become ceilings of performance for any youngster;
> (c) that the provision and support of qualified teachers is primary to the accomplishment of these goals;
> (d) that teachers at all levels and in all geographical areas should have the opportunity to select from among the growing array of alternative teaching styles and materials those that best meet the needs of their students;
> (e) that teachers of mathematics continue to be supported within their school systems by qualified resource specialists in mathematical curriculum and instruction.

NACOME also made a number of points regarding reasonable and essential features of a contemporary mathematics curriculum, including:

> (i) that concrete experiences be an integral part of the acquisition of abstract ideas;
> (ii) that the opportunity be provided for students to apply mathematics in as wide a realm as possible;
> (iii) that "computer literacy" courses involve student "hands-on" experiences using computers.
> (Conference Board of the Mathematical Sciences, 1975)

More recently, the National Council of Teachers of Mathematics (NCTM) of America published a report "An Agenda for Action" (1980) which listed a series of recommendations for school mathematics of the 1980s. These were that:

(i) problem solving be the focus of school mathematics in the 1980s;

(ii) basic skills in mathematics be defined to encompass more than computational facility;

(iii) mathematics programs take full advantage of the power of calculators and computers at all grade levels;

(iv) stringent standards of both effectiveness and efficiency be applied to the teaching of mathematics;

(v) the success of mathematics programs and student learning be evaluated by a wider range of measures than conventional testing;

(vi) more mathematics study be required for all students and flexible curriculum with a greater range of options be designed to accommodate the diverse needs of the student population;

(vii) mathematics teachers demand of themselves and their colleagues a high level of professionalism;

(viii) public support for mathematics instruction be raised to a level commensurate with the importance of mathematical understanding to individuals and society.
(NCTM, 1980)

Finally, the Cockcroft Report (1982) is a major contribution from the United Kingdom. The report addresses a wide range of concerns including: the aims and objectives of mathematics teaching, the mathematical needs of adult life, employment and further and higher education, the state of mathematics in British schools, and problems concerning teachers and teacher education. The conclusions and recommendations have much in common with the other reports mentioned above.

The support for many of the views and recommendations of such reports amongst the Australian mathematics education community can be seen by the number of publications relating to such issues as basic skills, problems solving, the place of calculators and computers and so on. In addition, in 1980, the Federal Government launched the Australian Mathematics Education Program (AMEP) which was to be funded through the Curriculum Development Centre (CDC). The goals of AMEP are:

(i) to act as a focus and centre of communication exchange between teachers, systems, states and institutions and thus help to foster a national view of mathematics education (K-12), and awareness of its importance in our society;

(ii) to assist teachers to be more effective by helping to develop positive attitudes to learning mathematics, and to help the community at large to understand better the meaning, relevance and importance of mathematics in an advanced industrial/technological society such as ours.

AMEP sees its major thrust related to the area of problem solving in mathematics.

> To base the teaching of mathematics on problem solving means that the teacher must be concerned about the active search (attitudes) and techniques or strategies (processes) as well as knowledge (content) in planning a mathematics curriculum. The overall intent of AMEP is to facilitate and encourage the development and spread of sound practices in the teaching and learning of all aspects of problem solving, and the incorporation of good practices into the total mathematics curriculum.

The closing of CDC and consequent placing of AMEP in limbo as regards funding is a matter of concern. There are a number of projects currently supported by AMEP operating with a minimum of funds at centres throughout Australia. Difficulties associated with trialling materials and transferring them to other states mean that some first class curriculum development is in danger of being lost to the Australian mathematics education community.

Given this brief background, we now review Australian research on curriculum which has been reported in recent years.

M2.1 Primary

As might be expected given the core nature of mathematics in the primary school curriculum, there have been many reports published and only a few will be considered.

Blakers (1978) briefly reviewed changes to the mathematics curriculum during the past 30 years. In the 1950s the primary school programme consisted essentially of arithmetic. By contrast, the Australian pattern in 1978 was that curricula tended to have less emphasis on skills and more on structure; some work on set language; and material on measurement, spatial relations and the beginnings of probablity and statistics. Evidence suggests that programmes reflected a fairly formal attitude to number and structure despite the emphasis of curriculum projects like Nuffield on activities and problem solving. Jones (1979a) looked at changes in primary mathematics in Queensland since the late 1950s. He described the effect of New Maths in 1966,and a 1975 modification of the primary mathematics programme. The content changes agree with Blakers' reviews. Owen (1979) considered the aims and objectives of teaching mathematics and listed nine major aims. Within this framework, he made a comprehensive list of specific objectives covering all aspects of mathematics teaching and related these to Piaget's stages of development.

In recent times, there has been a vigorous "back to the basics" movement based largely in the popular press though with some input from sections of the mathematics community. Hughes (1982) analysed the numeracy debate in terms of the real concerns that were being expressed and discussed the question of what should be our emphasis in general mathematics education. He quoted research that suggested that the actual mathematics used in employment is much wider than we may have imagined and went on to suggest a framework for making decisions about what are the mathematical needs of all children. It included essential mathematics for survival in society, mathematics for vocation, and mathematics for intellectual development. He concluded:

> The easy answer for us is to accept the demands of the critics and offer a simplified and highly focussed mathematics teaching. To do so would be to deny the richness that the subject offers and the range of opportunities to which all individuals are entitled... Our task as mathematics teachers is not to give a poorer diet but a richer one, a diet which is more ambitious, better balanced and better presented. (Hughes, 1982)

Thornton (1979) discussed the meaning of the word 'numeracy' in relation to common misunderstandings about it, and emphasised the highly conceptual nature of numeracy. Contrary to popular opinion, he believed numeracy to be very hard to assess and to contain unavoidable intrinsic teaching difficulties. Ransley (1980) considered mathematics for primary children with special needs and questioned what ought to be regarded as basic skills. Rathmell (1981) discussed the teaching of basic facts of arithmetic in order to develop immediate recall. Thornton (1981) gave suggestions for facilitating learning in a number of mathematical topics found to be particularly difficult for primary school children including subtraction, long division and fraction skills. Wheeler (1982) looked at the general question of remediation in mathematics. He also expressed scepticism about the growing interest in "diagnostic and prescriptive mathematics" and the setting up of "remediation clinics" in the USA.

Booker (1978) and Clements (1978) discussed the importance of spatial ability as a component of the mathematics curriculum and reviewed relevant research. Booker claimed that teaching methods can affect visual abilities, particularly those methods that involve children in manipulatng apparatus and equipment. Clements suggested that research is leading to balanced sets of spatial activities for children. The dominance of primary programmes by textbooks is raised by Hannah(1980). This leads to students thinking of mathematics as what is contained in the yearly text. Mathematics is perceived of as filling spaces, completing tests and occasionally working on a puzzle. This dominance in part has led to the Education Department of Western Australia revising the primary mathematics syllabus. It provides a wealth of ideas for activities to help teachers achieve the requirements of the new syllabus with a clear intention to promote change in the process by which mathematics is taught. Hannah expressed concern about the lack of readiness of teachers for an activity, textbook-free approach as recommended, and pointed out the need for appropriate support mechanisms. In Victoria, a new set of measurement guides has recently been published by the Education Department. These also put strong emphasis on an activity-oriented approach.

A number of articles addressed questions concerning calculators and computers. Daffey (1979) looked at ways in which calculators have been, and can be, used in primary classrooms and made suggestions for future research. Ferres (1981) surveyed current practices and attitudes towards calculator usage of grade 4 to 8 teachers in Government schools in Melbourne. He found that:

(i) very few teachers use calculators as an instructional aid to learning;

(ii) there was a lack of awareness of the likely impact of calculators on mathematics teaching and learning;

(iii) there was general agreement that calculators have a role to play and a strong belief in the need for inservice training on the effective use of calculators as aides to learning;

(iv) there existed a general wariness about readily introducing calculators into the classroom at these levels.

Koop (1979) suggested guidelines on the type of calculator to use, how to use it, and the availability of calculator curriculum materials. Farrell (1981) discussed computer usage in primary schools under six main headings: computer literacy, computer programming, problem solving, simulations, computer-assisted instruction or learning, and administration. He warned that "failure to provide adequate training and suitable materials is a certain guarantee that the use of computers in primary education will fail".

M2.2 Secondary

Again, there have been many reports published in this category and only a few are considered here.

Blakers (1978) reviewed major changes in content since the 1950s and suggested that associated changes in attitude could

eventually prove more significant. Obvious changes are the decline in formal Euclidean geometry and an increase in emphasis on probability and statistics at middle school levels. Increased attention has been given to the growing number of less able students remaining in school at years 11 and 12. Some States have developed special courses for such students. These courses have had limited acceptance by students who tend to see them as lacking in relevance compared with traditional courses at these levels. The Australian Academy of Science curriculum project is an example of a national project designed to cater for less able students at year 11, but it appears to have had rather limited impact so far. Jones (1979b) looked at changes in junior secondary mathematics in Queensland since the late 1950s and found that, while there was some difference in content, presentation was still very formal. This has led to a degree of local criticism. Rosier (1980) did a content analysis of mathematics courses for age 13 students and for courses at year 12. He found that the topics generally included in the 1978 mathematics curriculum for 13 year old students covered a much wider range than in 1964. This gave students a wider exposure to the richness of mathematics but the variety could have decreased the time available for basic skills and concepts. At the year 12 level, the number of courses available in 1978 was larger than in 1964 with a consequent increased range in topics covered. In particular, there was an increase in the number of non-specialist mathematics courses at this level. McQualter (1980) reviewed changes in mathematics education from 1945 to 1979. He described the "new mathematics" movement as the result of:

(i) a growing dissatisfaction with the then current school mathematics curriculum;
(ii) the increasing use of mathematics by all sections of society.

Nisbet (1978a and 1978b) also discussed the impact of "new mathematics" in Australia including factors contributing to the "new maths" movement, the Australian version of "new maths", reaction to its introduction in Australia and the continuing revolution in school mathematics. Firth (1981) expressed concern for a number of problems relating to the mathematics curriculum. He claimed that: there exists a shortage of mathematics teachers and consequently mathematics is often taught by unqualified teachers;

that since mathematics is compulsory in the junior secondary school, teachers are under little pressure to make the subject meaningful or motivating; and that there is a wealth of evidence to suggest that mathemtics is dull and unenjoyable for many youngsters. Kennedy (1981) observed that more than one third of Victorian state high schools have at least one teacher in the mathematics faculty with neither tertiary study in mathematics nor mathematics method training. Other trends she considered include: the increasing demand for year 11 and 12 non-academic mathematics courses; the important role of the mathematics co-ordinator, particularly in the area of curriculum development; the drift away from dependence on a single textbook resource in Victorian schools (only 10% of state high schools use a pupil-purchased textbook as their only resource and over half do not require students to purchase a book at all); and the increasing number of schools which have acquired micro-computer facilities. By contrast, Davey & Nisbet (1979) surveyed Queensland schools and determined that Queensland mathematics teachers were heavily textbook oriented, though they recognised a need for greater usage of non-textbook resources.

One of the major influences on the mathematics curriculum over the last decade has been the emphasis on school-based curriculum development, particularly in Victoria and South Australia. Lowe(1979a) described the importance of course planning in this context. He looked at: content-level; class grouping possibilities; organizational style within the classroom; the importance of concept and application as well as skills learning; and the need for careful unit planning.

Cribb (1982) reviewed the history of school mathematics curriculum development from 1972 to 1982 in Victoria. The major features are:

(i) 1972 - curriculum freedom encouraged with removal of intermediate and leaving certificates;

(ii) work of Z.P. Dienes influenced formation of the Study Group for Mathematics Learning (SGML) which was responsible for producing many new ideas and resources;

(iii) scepticism of SGML led to the second wave of reform which saw the rise of individualized mathematics courses with the accompanying weaknesses of poor coordination and planning;

(iv) 1978 - the Secondary Mathematics Committee (SMC) of the Victorian Education Department produced the package 'Guidelines in Mathematics Activities', a compendium of teaching ideas to support an active approach to teaching mathematics. However, no support mechanisms for encouraging their use were available;

(v) 1981 - SMC undertook production of a more specific and pragmatic document, the Curriculum Development Guidelines, which became available in April 1982. The Guidelines contain explanation of steps involved in curriculum planning and development and give an example of a sample course for years 7 to 10.

Clarkson (1979) reviewed the development of the Rusden Activity Mathematics Project (RAMP) which commenced in 1973 as a Victorian attempt at providing a resource network for secondary teachers involved in school-based mathematics curriculum development. Evidence gathered suggested that experienced teachers, competent in traditional textbook-oriented styles of teaching, may not necessarily be capable of employing the techniques implicit in the activity-based orientation of RAMP. Winkles (1981) discussed a core curriculum approach in years 7 to 10 at a Victorian high school.

In response to the 'back to the basics' movement McCreddin (1980) referred to the 1977 National (USA) Council of Supervisors of Mathematics' position statement on basic skills. The supervisors had isolated ten areas of skills that have been widely endorsed by mathematics educators from several major western countries. These are:

(i) problem solving;
(ii) applying mathematics to everyday situations;
(iii) alertness to the reasonableness of results;
(iv) estimation and approximation;
(v) appropriate computational skills;
(vi) geometry;
(vii) measurement;
(viii) reading, interpreting and constructing tables, charts and graphs;
(ix) using mathematics to predict;
(x) computer literacy.

Briggs (1981) looked at recent policy statements on problem solving which in summary say that "problem solving was consistently high in priority for increased emphasis in the 1980s," and "the climate appears highly favourable for implementing curricular change which would focus on problem solving". He reviewed the literature on problem solving and concluded with some potential research questions. Lowe(1979b) outlined early developments in the Reality in Maths Education (RIME) project in Victoria which has focussed on problem solving as a major thrust of mathematics education for the 1980s. RIME is currently building up a bank of problem solving lessons for adoption by schools after substantial trialling. RIME is one of the projects subscribed to, and supported by, AMEP.

Bloom (1980) described the application in Western Australia of the UK 'Maths for the Majority' project (MMP) directed towards the less able student. She indicated that there have been many calls for the mathematics curriculum to place more emphasis on applicable mathematics and considered MMP as an excellent start in that direction.

Gough (1981) asked what mathematics ought to be taught to gifted children and suggested a radical approach to introduce these children quickly to the frontiers of current mathematics research. Long (1980) also looked at the problem of selecting appropriate materials for mathematically talented students.

A number of writers addressed questions concerning calculators and computers. Koop (1979) and Ferres (1981) were referred to in section M2.1. Feiglin et al. (1979) surveyed calculator usage in Victorian post-primary schools and found amongst other things that:

(i) calculators are being used by students without teacher knowledge and control;
(ii) there is a scarcity of appropriate teaching materials to accompany calculator usage;
(iii) many respondents believed that calculator usage should be reserved for remedial classes and for gifted students.

These findings largely agree with those of Ferres. Malone (1977) reviewed computer developments in school mathematics across Australia - unfortunately, his review is now dated. Barnsley (1981) described the current state of computer education in the Northern Territory including: hardware used and available; facilities; use of microcomputers both in computer courses and as a resource across the curriculum; and the importance of inservice. Power and McBryde (1978) investigated two computer mathematics programmes involving the setting up of a mini-computer facility and its use in the teaching of courses in computer mathematics and social mathematics. McDougall (1980) raised a number of concerns related to computer developments:

(i) computing equipment (except in Tasmania and possibly South Australia) has appeared in schools in a relatively unplanned way;
(ii) whether appropriate aims of computer education in schools are being achieved;
(iii) the possibility that the teaching of computer programming (as against using computing technology to enhance mathematics teaching) might be encroaching on time previously allocated to mathematics.

Other educators have expressed concern that since mathematics teachers are those most likely to be involved in the teaching of computer science and computer literacy courses, this will ultimately compound the problem of shortage of qualified mathematics teachers. Cockcroft (1982) showed that, in the UK, an estimated 600 good mathematics teachers have been "lost" in staffing computer education courses.

M2.3 Tertiary

Only a small amount of material has been published in Australia on tertiary mathematics curricula. Watson (1981) reviewed individualized mathematics programmes at Australian tertiary institutions and asked for more quantitative evaluation of such innovations. She found that the first use of the Keller plan, the most familiar variation of individualized instruction, was made by Smythe at the Australian National University in a first year calculus course. The main features were:

(i) mastery of the subject matter which had been divided into two-week units;
(ii) self-pacing which allowed students a large degree of freedom in completing the work;
(iii) individual contracts between students and tutors;
(iv) a grading system which did not discriminate against initial failure and guaranteed a pass on successful completion of a prescribed number of unit tests.

Despite some disadvantages, including student procrastination and the workload of setting up and administering the scheme, Smythe's reaction was positive. A similar programme was developed by Prokhovnik at the University of New South Wales in a third year mathematics course for chemical engineering students. Students gave a generally favourable reaction to the course and reported an improved attitude towards mathematics. Watson ran a Keller type course at the University of Tasmania in a first year subject dealing

with topics in finite mathematics. Students were allowed to choose from several forms of assessment and time deadlines were imposed in some of the assessment options. Student reaction was generally positive.

The most widespread use of individualized instruction, however, has occurred at Monash University where seven different individualized courses in mathematics were organized between 1976 and 1980. The subjects ranged from calculus for arts students to engineering mathematics and statistics. Other instances of individualized instruction have occurred at the newer universities such as Griffith and Murdoch where more flexible admissions policies have brought students into mathematics courses without the traditional mathematics background. Watson also noted colleges of advanced education with similar programmes to the newer universities. These included Canberra CAE where a Keller type course was implemented. At Capriconia IAE, a British project, Polymaths, a preparatory course in mathematics designed specifically for mature students, was adapted. A more ambitious programme of a non remedial nature was instituted at Swinburne IT for first year students in Mechanical Engineering in 1974. It involved applied mechanics, physics, and mathematics - about one-half of a student's workload - and received a positive response from staff and students. After three years of operation, an evaluation of the mathematics component found that:

(i) when the self-paced group took the same final examination as a group taught by the traditional classroom method, the self-paced group had a "better" (unquantified) pass rate;

(ii) part-time students, whose pass rates had previously been as low as 30-40%, attained a pass rate of 80%, similar to that of full-time students.

Bajpai (1980) surveyed mathematics courses for engineers in Australia and found considerable differences in electives and courses offered between institutions and between branches of engineering within institutions. Firth (1981) expressed the concern

that universities need to provide elementary bridging courses for those entrants lacking the mathematical prerequisites. Galbraith (1977) quoted American, British and Australian examples which suggest that conventional tertiary level courses have not provided students with a basic appreciation of the logic of mathematics.

In the TAFE area, the only report located was by Osman (1982) who discussed: the variety of trade mathematics curricula and their relationship to primary and secondary school mathematics; problems associated with remediation; and the need for methodological assistance for TAFE teachers given the range of student performance within a single class of students.

M3 Teacher Education in Mathematics

M3.0 Introduction

Despite the extent of research in mathematics education in Australia over the last two decades, very little has been devoted to teacher education programmes. Overseas research in this area has concentrated on:

(i) mathematical understanding and competence;

(ii) attitudes towards mathematics and the teaching of mathematics;

(iii) teacher characteristics in the classroom and their relation to pupil achievement.

Results so far can be best described as inconclusive. Jones (1978) saw the need for more research in a number of areas including;

(i) studies relating selection procedures to performance in teacher education programmes and to work success;

(ii) studies relating performance in teacher education programmes to work success;

(iii) a review and comparison of mathematics and mathematics education requirements for teacher education programmes in Australia, followed by the development of a set of national guidelines for the preparation of mathematics teachers at both the primary and secondary level;

(iv) studies to evaluate the effectiveness of "end on" programmes, integrated programmes, "sandwich" type programmes, school based programmes, "competency based" programmes and other innovative developments in teacher education;

(v) studies relating teacher attitudes towards mathematics and teacher effectiveness in providing meaningful learning experiences.

He asserted that the

> ....skills we require teachers to practise are typically determined by wisdom rather than research.

Regarding teacher effectiveness, we can be more certain about factors that detract from "effectiveness" than we can be about factors that contribute to it. For example, it is clear that a dislike of mathematics detracts from effective teaching of mathematics. Confusions about mathematical concepts, apparently widespread amongst primary teachers and present also amongst secondary teachers, decreases teacher effectiveness. Unfortunately, a love of mathematics and a sound knowledge of mathematical concepts do not themselves imply an ability to communicate ideas successfully to children. It would appear that these factors interact with many others involved with the teaching-learning process. In terms of professonalism of mathematics teachers, Ramsey's list (see section S3.0) - replacing the word 'science' by 'mathematics' - would be accepted by many mathematics educators as being associated with effective teachers of mathematics.

M3.1 Primary

Start and Strange (1980) reported on a 1974 survey undertaken of primary reading and mathematics course elements in eight teacher-training colleges of Victoria. It was found that there was an inadequacy of compulsory work in mathematics at most colleges. For example, a judicious choice of institution could mean that a student might escape with 12 hours of mathematics during their entire course. The average amount of compulsory mathematics was 34 hours and the average amount of optional work (available) was 46 hours. These figures may well have changed since 1974, but no more recent data was located. Mansfield (1981) surveyed all institutions concerned with preparation of primary school teachers in 1978 to determine:

(i) the structure of compulsory units and methods used to teach them;

(ii) details of non-compulsory units;

(iii) the number of hours allocated to mathematics and mathematics education;

(iv) the major emphases of those programs.

The major findings included:

(i) a preference for integrated content and method studies;

(ii) colleges made greater use of laboratory and workshop techniques than universities;

(iii) many courses fell well below the suggested compulsory content of time of 75 hours;

(iv) major emphases were competence, teaching skills and attitude improvement;

(v) respondents considered inadequate time was spent on mathematics education.

Many concerns are expressed regarding the mathematical competency and attitudes of primary teachers. A. Jones (1979), a former Director-General of Education in South Australia, encapsulated these concerns when he opened the third biennial conference of the Mathematics Education Lecturers' Association (MELA) by saying that:

> ....the first blow you can strike for numeracy in the primary school is to insist that the selected entrants to your institutions have completed a full couse in secondary school mathematics.

Pateman (1981) was concerned that:

> By and large individuals who opt for primary teaching have abandoned (or have been abandoned by) mathematics as soon as

possible during their post primary education. They get through their courses by reaching minimum standards, and soon fall back on that methodology, or mythology, which actually failed them in their schooling, so producing the next generation of primary teachers.

It is not surprising, amongst all this doom and gloom, that a number of studies have concentrated on improving attitudes and competencies of prospective primary teachers. Schofield and Start (1978) reviewed research on the relationship between attitude and achievement among student teachers which seems to discount any positive relationship. They criticized the assumption that attitude to mathematics was a single dimension. In their investigation, using multidimensional instruments, substantial positive correlations with mathematics achievement were found. There were significant correlations between achievement and positive attitudes towards teaching mathematics to children. The question of whether positive attitudes towards teaching mathematics produces higher mathematics achievement amongst children awaits verification.

Jones and Irons (1978) investigated two approaches to teaching mathematics and mathematics methods to pre-service primary teachers. In the first approach students studied mathematics during one semester in their first year and mathematics method during one semester in their second year. The second approach involved the same allocated time and content as the first approach, but was presented in an integrated fashion over the two semesters. They found that:

(i) attitudes towards mathematics and the teaching of mathematics underwent a favourable change for students in the integrated programme, though evidences of this change did not appear until well into the second semester. Initial attitudes in the integrated programme were strongly resistant to change;

(ii) students in the integrated approach rated it more highly than those in the traditional programme on factors such as relevance and appropriateness of facilities and materials, but there was no difference between the ratings in respect of suitability of instruction or fairness of assessment.

The question of whether there is a difference between the teaching performances of student teachers and their pupils' performances in later years is as yet unanswered. Squire (1979) also looked at mode of intruction and attitude in teacher preparation courses and concluded that:

(i) seminar/workshop style showed significantly greater improvement in attitude towards mathematics than did lecture style;
(ii) seminar/workshop style fostered a favourable attitude towards mathematics.

Schleiger and Doig (1980) also found that a combined mathematics and mathematics methods course using an active, materials handling approach resulted in positive attitudinal changes compared with traditional, lecture-style approaches.

Dettrick (1982) investigated the mathematical competencies of primary teachers, based on a sample of 388, which included teachers of all grades, specialist teachers and principals. His findings include:

(i) average achievement on basic mathematical competencies tests was 68%, considerably lower than the 80% competency level regarded as reasonable;
(ii) year 11 background is a sort of "mathematical watershed"; those teachers who had not taken mathematics as far as year 11 were generally much poorer performers than those with year 11 mathematics studies or above;
(iii) there were inconsequential differences in competency between one, two and three year trained primary teachers.

Anderson (1982) reviewed research on the mathematical and spatial competence of Australian pre-service and in-service infant, primary and secondary teachers and suggested large gaps existed in the literature.

M3.2 Secondary

The only local studies located which report on secondary teacher education are by Galbraith (1977, 1982). In his 1977 report he gave preliminary findings on the extent of basic concept acquisition by prospective secondary mathematics teachers:

> The most obvious feature is the weak performance on a test in which the emphasis was on basic mathematical knowledge and thinking rather than on manipulation of symbols or the performing of complex algorithms.

He analysed the results with respect to: institution type (university versus CAE); extent of studies in pure mathematics (3 years or more versus less than 3 years); recent nature of mathematics studies; and liking for mathematics. No significant differences were found except that those who liked mathematics scored higher. He concluded:

> There are obvious implications for teachers of mathematics at all levels. The results .... suggest that mathematical appreciation and awareness is not necessarily increased by providing more of the same course. This supports the claim... that an urgent need exists for different kinds of courses with different aims.... The (one) significant result... seems surprising (in) that less than one third of all students choosing a career in mathematics admit a strong liking for mathematics.

In his 1982 study, Galbraith reported on an extension of his earlier work. He tested for "mathematical vitality", which might be approximately defined as awareness of underlying logical processes and basic (year 12 to first year tertiary) mathematical comprehension. Results appear to lend support for the following hypotheses:

> (i) misconceptions and misunderstandings learnt at secondary level tend to remain and are resistant to correction through the agency of advanced level courses;

(ii) the level of mathematical vitality achieved by secondary graduates is independent of local contexts with regard to precise syllabus content and curricular emphases;

(iii) the level of mathematical vitality achieved by graduate students is independent of particular institutions or mathematics units studied.

He conjectured that:

(iv) factors relating to the way in which mathematics is presented and learned dominate all other influences;

(v) mathematical vitality is not enhanced by the process of studying more mathematics at secondary level.

(vi) mathematical vitality is not enhanced by the process of studying more mathematics at tertiary level.

M3.3 In Service Education

No recent studies were located on either the involvement of practising mathematics teachers in inservice activities, or evaluation of these programmes. It is clear, however, that there has been an upsurge of inservice activities over the last decade offered by a range of institutions including colleges, universities, Education Departments and subject teacher organisations. Some in-house evaluation studies may have been carried out, but these have not been reported in the literature.

M4 Support for Curriculum Development

M4.1 Primary

The only study located that referred specifically to support for primary mathematics teachers was Dettrick (1982). In the context of investigating the mathematical competencies of primary teachers (see section M3.1), he concluded that a substantial number of primary teachers urgently require the support of content-based inservice education. He saw this as preferable to other forms of support such as more elaborate teacher's guides, background material, etc. since these could not deal with attitude development and diagnosis and remediation of weaknesses.

In Victoria, new measurement curriculum guides have been produced by the Education Department in the last two years. In contrast to earlier times, substantial efforts are being made to aid teachers in implementing the suggestions in these guides through inservice activities and consultancy services.

M4.2 Secondary

Cribb (1982) mentioned the lack of support for the implementation of the Secondary Mathematics Committee's Guidelines in Mathematics Activities (GLIMA) which were distributed to Victorian State high schools in 1978. Teacher feedback suggested that the ideas contained in GLIMA were useful. However, there was a wariness of involvement in radically new teaching methods implicit in an activity approach as compared with traditional methods reliant on textbook approaches. In connection with the new Victorian Curriculum Development Guidelines (see section M2.2), Cribb suggested that system support has been much more evident. The guidelines have been available to high schools since April 1982. They have only been made available to schools through the agency of regional mathematics consultants, who have assisted teachers in methods of using the guidelines. In addition, consultants are organizing regional workshops in:

(i) setting course parameters;
(ii) choosing a course structure;
(iii) choosing course content;
(iv) allocating time and deciding on sequencing;
(v) keying in resources.

It is as yet too early to evaluate the impact of this support.

Clarkson (1979) reviewed the impact of the Rusden Activity Mathematics Project (RAMP) which was an attempt at providing a resource network for secondary teachers involved in SBCD (see section M2.2). The project, begun in 1973, was organized as a continuing inservice training course. Review sessions and two day inservice courses were held during the first three years of the project. Many of these sessions were devoted to exploring and discussing the uses of the various concrete aids that were promoted by RAMP. Evaluation of the success of RAMP materials and strategies was informal. Some evidence suggested that experienced teachers, competent in traditional teaching styles, may not necessarily be able to employ techniques implicit in the RAMP rationale.

Barnsley (1981) pointed to the increasing demand from teachers in all states for inservice related to the use of computers. He listed a number of support mechanisms in the Northern Territory including computer related courses and departmental inservices.

M5 Participation in Mathematics

M5.1 Primary

All students participate in mathematics education at all levels of primary schooling. Differences in the amount of mathematics studied between the various states were listed in section M1.1.

M5.2 Secondary

All students participate in mathematics education to year 9. While no published data were located on year 10 students, most writers assume that the majority of year 10 students study some form of mathematics.

Rosier (1980) gathered data on changes at year 12 from 1964 to 1978. There was a marked shift in the range of mathematics courses available, including an increase in 'terminal' mathematics courses. There was little provision of these in 1964 but, by 1978, each State had one or more such courses. Enrolment figures for all year 12 students and mathematics students at this level were referred to the 'year cohort', defined as the number of students in each State at the first secondary school level in the relevant earlier year. Thus in Victoria for year 12 students in 1964, the relevant year cohort was the number of students in year 7 in 1959. A summary of the data is given in Table 4 (note that the ACT was included in NSW in 1964). The data shows that the holding power at year 12 level increased from an overall Australian value of 22% in 1964 to 35% in 1978. The national percentage of year 12 students studying mathematics remained constant at 60%, but differential changes occurred among the States. The net effect was an increase in the percentage of the year cohort studying mathematics in all States with the overall Australian value rising from 13% in 1964 to 21% in 1978. However, it needs to be remembered that, with the increase in 'terminal' mathematics courses, a large proportion of the 1978 mathematics students were not undertaking courses leading to subsequent specialised studies involving mathematics.

		ACT	NSW	VIC	QLD	SA	WA	TAS	AUST
1964	% of year cohort in year 12		28	20	21	14	19	7	22
	% of year 12 studying mathematics		53	47	89	64	97	40	60
	% of year cohort studying mathematics		15	10	19	9	19	3	13
1978	% of year cohort in year 12	68	36	33	37	36	34	24	35
	% of year 12 studying mathematics	66	72	50	56	53	64	32	60
	% of year cohort studying mathematics	45	26	16	21	19	22	8	21

Table 4. The holding power of year 12 mathematics courses.

Not all States have kept separate statistics for males and females, but the available data shows that the percentage of female students increased between 1964 and 1978 both for year 12 enrolments and for the number of year 12 mathematics students. However, this increase was to a large extent due to the provision of less specialised courses.

A number of studies refer to the sex factor in participation in mathematics in the senior secondary school. Atweh (1980) reviewed research concerning females' avoidance of mathematics and suggested possible remedies. Morgan (1979) carried out an investigation of students moving into year 11 to determine the factors that led them to continue with non terminal mathematics. Over two-thirds of the students sampled sought advice from one or more persons regarding the decision (usually parents, relations and peers rather than school personnel or career counsellors). The advice was typically more encouraging and less negative for boys than for girls, although there were no overall differences in mathematical ability, as measured by year 10 performance, between the two groups.

Crowdy (1980) found that, of students in ACT secondary schools completing their studies at the end of 1978, 20% of males completed a double major or major/minor in mathematics compared to 7% of females, and 18% of males completed no mathematics course compared to 28% of females. Widdup (1981a) described a range of factors that led to lower participation by females and suggested ways that schools can remedy the problem. Leder (1981) and Firkin (1981a) discussed several relevant issues related to girls' performance and participation in mathematics. They confirmed Rosier's contention that while more girls are studying mathematics at the year 12 level, they in general are enrolling for the so-called 'softer' options. For example in Victoria, disproportionately more males than females have enrolled in recent years for the more academic Pure and Applied Mathematics courses at year 12.

Tickell (1981) reviewed the current situation in mathematics in Victoria and discussed the trend from Pure and Applied Mathematics to General Mathematics as well as the low participation of girls. Osman (1981) looked at participation patterns in mathematics in South Australia. She found that, at year 11 in 1979, only 40% of males and 27% of females in State high schools studied a mathematics subject. At year 12 level in that year, 36% of males and 14% of females enrolled for Mathematics I and II while a further 31% of males and 27% of females enrolled for the alternative, Mathematics 1S. (See also the discussion of Walsh's investigation in section S5.2).

M5.3 Tertiary

Douglas (1981) and (1982) analysed those who completed the mathematical requirements for Honours and Higher Degrees in Pure Mathematics, Applied Mathematics or Statistics over the years 1959-1979. His data on Honours Degrees showed low participation rates by women and a general decline in the overall numbers completing Honours or Higher Degrees over the last few years. No other studies of participation in mathematics courses at the tertiary level were located.

M6 Knowledge Outcomes

M6.0 Introduction

Studies on the performance of students on concepts and skills in mathematics are plentiful at both primary and secondary levels. While most concentrate on either primary or secondary age children, a few more general studies blur the distinction between the two levels. These will be referred to in section M6.1 below. There is a wealth of overseas research on children's concept and skill acquisition, much of it inspired by developmental psychologists. Despite the extent of this research there is still substantial disagreement with respect to cognitive outcomes and related factors.

M6.1 Primary

A number of reports have been written on the question of numeracy (see also section M2.1). Donovan and Coates (1978) analysed the ACT data that contributed to the 1977 report on Australian Studies in School Performance. Of 10 year old children sampled, 74% achieved mastery in the numeration test compared with the Australian figure of 75%.

Hughes (1982) discussed public concerns about mathematics performance:

> It is an old and regularly repeated claim that schooling is not what it was and most parents seem fairly certain that their children are not working as hard or achieving as much as they did.

He pointed out that in Tasmania, where standardised test results at the primary level have been kept for over 40 years, the indication was not of decline but a slight improvement in all areas from mechanical arithmetic to problem solving. Hughes also discussed changing factors that need to be kept in mind when discussing numeracy. These include:

(i) the increasing proportion of students remaining in school to higher secondary levels;

(ii) differences in these proportions between countries; this is important when comparing students from one country to another;

(iii) the pressure for a "return to the basics" which is perhaps less related to arithmetic performance than to a demand for order and discipline;

(iv) decline in performance is really a red herring in that the real concern should be with whether students are able to meet the needs of today's society adequately and face the challenges of the future.

Item (iv) leads us to consider the computer, the electronic calculator and the necessity of accepting the implications of modern-day technology. McCrae (1979) considered the effect that calculators will have on the development of numeracy. He reviewed various definitions and concluded that the calculator was not a threat to numeracy but [illegible]s:

> ... the key to numeracy for many people who, in the past, have been unable to develop and use an appropriate range of basic mathematical skills because of their inability to perform straightforward calculations without undue anxiety.

Foster (1979) investigated the effect of a calculator-assisted programme on the mathematics achievement of year 3 children in a Tasmanian primary school. He found that on various arithmetical tasks, the achievement of students who had worked with calculators was significantly better than that of those without calculators. It should be noted that the mass of overseas evidence agrees with this result! Hayes (1979) reviewed research on the impact of electronic calculators and suggested lines for future research including:

(i) the effects of using calculators in teaching particular topics;

(ii) the effective use of calculators.

A number of workers have looked at the relationship between mathematical understanding and performance, and language factors. Clements (1982) carried out a comprehensive overview of Australian research ranging from comprehension of mathematical language to research inspired by psycholinguistic theory. Kissane (1979) reviewed some of the research on the relationships between language and mathematics and gave some suggestions as to action mathematics teachers could take. These included:

(i) checking on what problems exist in the teachers' classrooms;
(ii) getting children to say in their own words what the problem is about;
(iii) asking students to read aloud from their textbooks;
(iv) choosing textbooks carefully.

King (1980) looked at mathematics performance and reading at a time when:

> Mathematics teachers are being bombarded with mathematics schemes, packaged programs, books for the fast learner, books for the slow learner, reproducible worksheets, workcard kits, and many more "new, better, and revolutionary" approaches to mathematics.

His conclusion is that researchers and teachers are becoming aware of language as a problem in mathematics learning and that ways of overcoming these difficulties lie in mathematics teachers trying to teach children appropriate reading strategies.

Hewitt (1980) investigated a different language problem of factors relating to the school performance of students from non English speaking backgrounds. His findings included:

(i) 8% of migrant students did not understand English sufficiently well to cope with normal classroom lessons and one third needed remedial assistance with reading or number work;
(ii) students from Southern European backgrounds appeared to be the most seriously disadvantaged.

Newman (1977) analysed year 6 low achieving pupils' errors on written mathematical tasks and found that approximately:

(i) 13% of errors were due to inadequate reading ability, with more boys in difficulty than girls;

(ii) 22% of errors were related to the inability to explain the meanings of questions, or otherwise demonstrate understanding of questions, even when pupils could read them;

(iii) 12% of errors arose with pupils who could read and understand the meaning of the tasks but could not identify the appropriate mathematical processes;

(iv) 26% of errors related to pupils' inability to apply correctly the relevant process skills;

(v) 25% of errors related to "careless slips".

Thus for about 35% of the errors made by the low achievers, the pupils concerned failed to arrive at a point where they could even begin to apply relevant mathematical knowledge or skills. The importance of Newman's research lies in the conclusion that, when an incorrect answer is given to a mathematical task, it did not necessarily occur because the pupil lacked the requisite mathematical knowledge or skill; there could be any of several reasons for the pupil's difficulties. The implications for teaching are clear.

Conroy (1981) looked at language factors in relation to mathematical tests and, in particular, at the assumptions that test writers made. An investigation was made of 33 words in the ACER CATIM (Year 6) test, each word being essential in one of the test items. These words would also be commonly found in a wide range of similar tests. Children in years 4 to 9 were used in the study. Results showed that 80% mastery was achieved on no item. The study was a pilot one and a more extensive project with a much larger sample is currently under way.

A number of studies have looked at sex differences in mathematical performance. Clements (1979) indicated that girls in years 5 to 8 performed significantly better than boys in the same levels on mathematical tests consisting of problems involving simple

numerical calculations and the application of straightforward logical analyses. Leder (1981) confirmed that differences in performance occur most frequently among post-primary students. Firkin (1981b) reviewed research that shows that between the ages of 10 and 14, the mathematical attainment of girls tends to decline relative to their previous performance, whereas that of boys tends to improve.

Other studies looked at concept deficits in infant grades (Mooney 1978), difficulties associated with Piagetian ideas (Langford 1980), the relationship between achievement and time on task (Smith 1980), and teacher perceived areas of difficulty in primary school mathematics (MacDonald 1981).

Dettrick (1978) investigated year 5 to 9 students' understanding of length, area and volume relationships and repeated the study with teachers of primary and junior secondary mathematics. Not surprisingly, students' mastery of these concepts was far from complete; more disturbingly, many of the teachers performed as poorly. He concluded that highly verbal textbook oriented teaching, unsupported by references to a wide variety of practical examples, is unlikely to produce conceptual improvement from the end of primary school to year 10. In a later study, Dettrick (1982) found disturbing performance on a series of basic mathematical competency tests by a large sample of primary teachers (see also section M3.1).

M6.2 Secondary

Rosier (1980) provided data about mathematics achievement of secondary students in Australia in 1964 and 1978. For 13-year-olds, there was a slight decline in overall national performance during the 12 year period. There was a slight increase in performance in Western Australia but a marked decline in Victoria. Rosier attributes the decrease, in part, to the reduction in the mean amount of time spent in class on mathematics over the period (see section M2.1). For year 12 students, the mean test scores increased over the period at the same time as the percentage of students studying year 12 mathematics subjects increased.

The question of numeracy at the secondary level has been raised by several writers. Maslen (1976) reviewed research which indicated that numeracy problems certainly exist, but he pointed out that Australian children have been shown to perform at the same level as children in the UK and USA despite the fact that Australian education systems receive a lower percentage of the gross domestic product. He considered related factors such as the 'new maths', the calculator and changing school populations. McCreddin (1980) challenged traditional definitions of numeracy and proposed a much broader range of basic skills than purely computational ones. He argued that over reaction in the USA to the alleged decline in standards now has teachers focussing on numeracy to the detriment of general mathematical competence. Kudilczak (1979) described a test instrument designed to test year 9 students on a range of mathematical survival skills essential for a person to cope with everyday living. He found that age, socioeconomic status, sex and school type each had a significant relationship with performance. A result of some interest was that older year 9 students (>13 years 11 months) performed less well than younger year 9 students.

Firkin (1981a) and Leder (1981) have analysed results at the Higher School Certificate (HSC) level in Victoria and found that boys have over recent years consistently out-performed girls. For example, throughout the ten year period from 1970 to 1979, a higher proportion of boys than girls obtained a grade of A in each of the three HSC mathematics subjects. They cited American research indicating that very few teachers actively encouraged even able girls to continue with mathematics, and relatively few were supportive to those who did. Other research they quoted indicated that teachers interact far more with boy than girl pupils at the secondary level, and that the quality and range of interactions with the two groups also differ. It is suggested that because of this, boys are likely to learn that, if they are not successful, it is because they have not tried hard enough, whilst girls are made to believe that failure is indicative of lack of ability. Widdup (1981) reviewed research on sex differences in mathematics ability and claimed that reports have tended to rely on studies of males and females with very different mathematics

backgrounds. When prior mathematics training is held constant, sex differences in ability disappear. That sex differences in achievement (as opposed to ability) and participation in mathematics beyond year 10 occur is not disputed.

Other studies looked at streaming (Pehrson and McClean, 1978, and Larsen, 1980), learning time and teaching for mastery (Ward 1979 and Romberg 1980) and children's use of imagery(Fary 1980).

S6.3 Tertiary

Galbraith (1977, 1982) looked at basic concept acquisition of prospective secondary mathematics teachers (students who had just completed three years or more of academic studies at tertiary institutions). He found substantial lack of understanding of basic mathematical concepts (see section M3.2). Cameron (1981) presented data on the poor performance of students with year 12 General Mathematics in mathematical subjects at Monash University. Phillips (1982) investigated the mathematics performance of first year engineering students at Swinburne Institute of Technology (see section M9.2).

M7 Investigatory Skills

M7.0 Introduction

Mathematics has traditionally been seen as a subject typified by: teacher-directed learning; "chalk and talk" techniques; emphasis on formal paper and pencil tasks; and reliance on textbooks. There have been a number of recent developments which promote investigatory skills in mathematics. These are characterised by phrases such as: "activity-learning"; "discovery learning"; "problem solving"; and "modelling". While there has been a deal of research in some of these areas, little of it appears to have been carried out in Australia. This may be because many concerted efforts to promote investigatory styles of teaching and learning are of fairly recent vintage, and previous involvement has tended to be isolated and unreported. It is to be hoped that developments like the Victorian Reality in Mathematics Education (RIME) project, the South Australian Mathematical Modelling project and the NSW Catholic Education system's primary mathematics curriculum based on problem solving will, in time, report on student outcomes associated with investigatory skills.

M7.1 Primary

The only recent study reported was by Bana (1978) who looked at the effects of distractions in non verbal problems on the problem-solving behaviour and performance of young children in years 1-3 The relationships of distractedness to sex, ability, conceptual tempo, grade, problem difficulty, and problem setting investigated. The findings indicate that young children are easily distracted by irrelevancies in a problem setting and frequently identify and attempt a different problem from the one assigned. It is also suggested that young children are not given sufficient experience with manipulative materials.

M7.2 Secondary

Clarkson (1979), in his review of the Rusden Activity Mathematics Project (RAMP), gave an informal appraisal of the success of the project. Evidence suggested that less able students coped more successfully than with formal styles. Whether they gained a deeper understanding of the concepts was left as an open question. Kissane, Mortlock and Malone (1979) reported on a large-scale Western Australian study of problem solving performance and attitudes of year 9 students. Each school used provided three classes and randomly assigned teachers to them. The classes had the following characteristics:

Group 1 - problem solving strategies and practice (teachers helped students with strategies and gave much problem solving practice);

Group 2 - practice only (teachers gave students problem solving practice but gave no assistance with strategies);

Group 3 - control.

The results indicated:

(i) no change in problem solving performance between any of the groups;

(ii) little or no improvement in problem solving ability for all groups over the year;

(iii) little change in attitudes towards problem solving.

The results confirm those of overseas studies which suggest that non-routine problem solving performance in school studies is strongly resistant to change, and that it is probably too late to alter approaches and attitudes in year 9 which have been established over the preceding eight years.

M8 Affective Outcomes

M8.1 Primary

Postle et al. (1977) investigated the relationships between children's attitudes to mathematics and three teacher variables: teacher's knowledge of mathematics; teacher's attitude towards mathematics; and the type of instruction employed by the teacher. Results suggested a much more complex structure of the concept of mathematics among teachers than among children. There was some evidence that a "modern" approach to teaching leads to a more positive attitude towards mathematics among children. Carroll et al. (1982) looked at primary school children's attitudes towards mathematics. It was found that:

(i) 11% nominated mathematics as the subject they liked the most, whilst 13% liked it the least;
(ii) 75% liked mathematics (1-3 on a 5 point scale);
(iii) 46% thought mathematics was the most important subject at school, whilst only 1% thought it the least important;
(iv) attitudes were entirely utilitarian - children did not see mathematics as a source of pleasure.

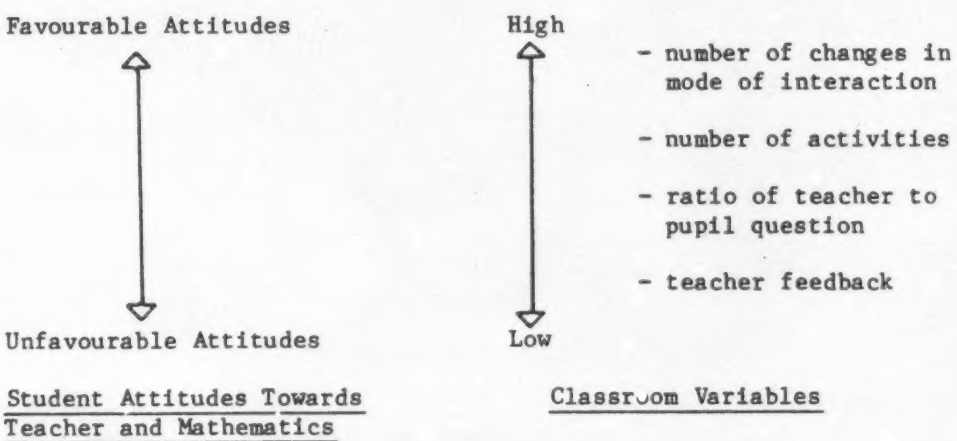
Several studies investigated the attitudes of primary and intending primary teachers towards mathematics and teaching, including Ferres (1981), Jones (1978), Squire (1979), and Schleiger and Doig (1980). Leder (1979) examined attitudes to teaching mathematics of a group of experienced teachers enrolled in a post-graduate course in special education. She found that most subscribed to an informal approach to mathematics instruction with no differences between males and females. Scheding (1982) investigated teachers' and prospective teachers' perceptions of the nature of mathematics and found that:

(i) the use and importance of rules and formulae in mathematical problem solving is consistently overrated;
(ii) teachers underestimate the importance of intuition;
(iii) teachers take far two narrow a view of mathematics as the study of numbers and the way they combine.

M8.2 Secondary

Rosier (1980) provided information on changes in attitudes of secondary students in Australia in 1964 and 1978. He found that 13-year-olds considered a knowledge of mathematics important for employment, and for an understanding of the environment. Year 12 students took a more neutral view of mathematics on these dimensions. Students in 1978 considered mathematics to be less important than did students in 1964. There were clear differences between the two groups in their perception of the ease with which the subject could be learned by most people, with the younger students considering it to be much easier. Both groups showed a deterioration in attitude towards school generally over the period, but there was no evidence of a corresponding deterioration for the liking of mathematics. It is disturbing to note that while mathematics performance at year 12 level has improved, students saw mathematics as less important.

Shield and Dekkers (1979) investigated the interaction of student attitudes towards mathematics and teacher behavioural characteristics in the mathematics classroom. It was clear that the teacher variable was highly significant since all teachers used whole class teaching and the same textbook, yet considerable differences were noted between student attitudes towards their teacher and school mathematics in different classes. Attitudes tended to be associated with particular classroom variables in the following way:



Widdup (1981b) described anxiety towards mathematics as an important factor in the dropout rates of girls from higher year mathematics courses and discussed their lack of confidence in themselves with regard to mathematics, a view unrelated to their actual ability.

M8. 3 Tertiary

Galbraith (1977) reported that less than one third of all students who had completed three years of academic study and were embarking on a year of teacher training admitted a strong liking for mathematics. Graham-Matheson and Shannon (1980) investigated attitudes to mathematics of technology students. They concluded that an increase in problem solving classes at the expense of lecture classes would have a positive effect on student attitudes.

M9 Transition to Higher Levels of Schooling

M9.1 Primary - Secondary

There is no doubt that serious transition problems exist relating to lack of coordination across the curriculum from primary to secondary school. In Victoria, primary teachers generally follow the Education Department's Curriculum Guides; because individual differences are catered for, the mathematical skills of primary students often vary widely. Thus when primary children reach the first year of secondary school, there are often large differences in background. Few secondary schools appear to have faced up to the challenge this poses. Often, it seems, teachers ignore these students' backgrounds and teach at some standard level that sells short those students with a rich and varied primary mathematics education while failing to cater adequately for the slower students whose background may be lacking. The secondary teacher heaps blame on the primary teacher for failing to get all students up to standard, while the primary teacher scorns the secondary teacher for failing to meet the challenge of individual differences. Some isolated attempts to encourage greater contact and liaison between the local secondary school and its feeder primary schools have been made in Victoria, but these have not been documented. Blakers (1978) referred to this aspect of transition:

> In spite of considerable efforts (and some success) in the production of individualised learning programs, it still seems to be the case that progression from primary to secondary school takes place at approximately the same age for every student. Moreover, the teaching in secondary schools generally begins with the assumption that all students have reached approximately the same level of achievement. These arrangements do not well suit a subject like mathematics, where individual aptitude, and rates of development, differ markedly. There is some evidence that mathematically able students have been held back more or less deliberately, a procedure that mocks educational claims that every student has the right to an education which permits the full development of his personal abilities.

Powell (1980) conducted interviews to determine views on three aspects of primary-secondary transition in Western Australia:

(1) students' perceptions of the problem (years 7 and 8);
(2) teachers' perceptions of the problem (years 7 and 8);
(3) what action to solve the problem is being undertaken in Western Australia.

With regard to (1), primary year 7 students identified both social problems and mathematics problems (they expected mathematics to become much more difficult). In contrast, the secondary year 8 students' social apprehensions were short-lived; far from finding mathematics too difficult, they found it a rather boring repetition of what had already been covered in the primary school. For (2), primary teachers of year 7 expressed frustration that students were likely to lack the individual support given by the primary school and the interaction between students and their year 8 teachers was expected to be impersonal with less emphasis on pastoral care. They were concerned about different teaching styles. Year 8 high school teachers faced the reality of the continuity problem of new students entering from a variety of primary experiences. Contentious issues were:

(i) records of student achievement. Some primary teachers saw this as a waste of time in that they appeared to be ignored by their secondary colleagues, whilst secondary teachers claimed that the information received was of little value;
(ii) primary teachers felt threatened and insecure about intake tests set "on high";
(iii) secondary teachers accused primary teachers of "poaching": doing interesting things in mathematics, and leaving all the dull sections for the secondary school.

In respect of (3), the most useful localised schemes operating in Western Australia were those in which there was an exchange of teachers between the two levels, either for short or extended periods, by; or an attempt at a common mathematics course over years 7 and 8. Some form of close liaison between primary and secondary schools and teachers was seen as essential.

Finally a number of suggestions for future study were made, including:

(i) more work on student perception of the problem of transition both socially and for mathematics;
(ii) a consideration of various forms of liaison;
(iii) the need for a body of information to be compiled listing tried and suggested ways of overcoming difficulties;
(iv) the idea of training a common core teacher from a primary feeder school attached to the secondary school for an extensive period.

Morgan (1979) investigated the decision to study year 11 non-terminal mathematics and found that generally boys received more encouraging and less negative advice than did girls. No other recent studies on transition from primary to secondary mathematics or the key point of year 10 mathematics to year 11 mathematics were located.

M9.2 Secondary-Tertiary

Osman (1981) examined participation patterns in mathematics in South Australia (see section M5.2). She noted that many students, especially females, are not well-equipped in mathematics for entry to a range of tertiary courses, particularly those of a scientific or technological nature. This suggests a need for tertiary institutions to give increased emphasis to the provision of bridging courses in mathematics. One suggestion is for students lacking the necessary prerequisites to take advantage of existing bridging programmes in mathematics offered in the TAFE collges. Osman considered that there was a need to investigate the current provision of bridging courses provided by a range of institutions. She also recommended a study of tertiary education courses, careers, etc. in which people may be prevented from participating, or successfully completing, because of a lack of an appropriate mathematical background. Osman believed that such an investigation could also make recommendations concerning the future provision of bridging courses in mathematics.

Walsh (1980) looked at Victorian enrolments in the three Year 12 mathematics courses for the years 1976-1979 and found that there was a strong swing from the Pure and Applied Mathematics combination to the single General Mathematics course. This imposed harsh constraints with respect to tertiary choice. In the case of students who studied no year 12 mathematics, tertiary choices were even more limited, with teacher training and commerce being virtually the only vocational courses available.

It is generally accepted that there is a positive relationship between overall student achievement at year 12 and tertiary performance. A number of studies have confirmed this for mathematics, e.g. Dunn (1981), and Mackay and Fary (1979). There have been strong concerns voiced in the press about students limiting career options by dropping more formal mathematics studies at year 12. For example, Holton (1981) pointed out that taking General Mathematics rather than the combination of Pure and Applied Mathematics in Victoria at year 12 might be a good tactic for maximising a student's chance of gaining entry into tertiary courses, but dramatically increased the student's chances of failure in courses involving formal mathematics.

Bodies such as the Australian Institution of Engineers have expressed concern about the quality of students entering tertiary courses, especially science and engineering. The problem of the flight from mathematics by girls is another area that has been alluded to earlier (see section M5.2).

In connection with the above, two studies have been carried out in recent years relating to the trend towards General Mathematics and away from Pure and Applied Mathematics in Victoria and the effect on performance in subsequent tertiary studies. Cameron (1981) showed how poorly students with only a General Mathematics background performed in mathematics subjects at Monash University. Only 33% of students who scored a D or worse in year 12 General Mathematics obtained a pass or better in first year tertiary mathematics. Half of the enrolments were from students with a General Mathematics background. By contrast, 60% of those who had obtained a D or worse in Pure Mathematics in year 12 obtained a pass or better in first year tertiary mathematics.

Phillips (1982) explored the influence of a student's mathematical background as well as other factors on the mathematics performance of engineering students at Swinburne Institute of Technology in 1980 and 1981. He confirmed Cameron's findings that General Mathematics students who enter tertiary courses involving formal mathematics were ill equipped to handle the mathematics content of those courses. Only 29% of those who had done General Mathematics in year 12 passed first year tertiary mathematics at their first attempt compared with an 80% pass rate for those who had done Pure and Applied Mathematics. Furthermore, students who obtained less than 70% (i.e. less than a B) in General Mathematics had very little chance of passing first year tertiary mathematics. Efforts made to correct deficiencies of the General Mathematics students through summer school and extra classes were found to be largely unsuccessful. Comparisons of first year mathematics performance of students from different school systems revealed little differences.

M10 Transition from School to Work

Only a few reports were located that addressed the school-work transition. Firkin (1981a) reported on research which has found that occupational aspirations of girls are more restricted than those of boys. Girls tend to reduce the potential range of occupations open to them because they pursue fewer mathematics and science courses. These provide the necessary prerequisites for a wide range of jobs. Thornton (1979) briefly discussed the relationship of numeracy to the world of work. The Western Australian Department of Education (1980) considered employers' perspectives of the effectiveness of schools and listed initiatives underway in the Department's schools to orientate students towards the world of work.

Nisbet (1981) investigated the business and industry sector's perception of mathematical terms, prompted partly by the considerable input of the business community in the "back to the basics" debate. He reported a Queensland survey of employers which found that school leavers required proficiency in: mental arithmetic; operations on whole numbers; fractions; decimals; percentages; use of a calculator; measurement; and scale reading. Algebra and trigonometry were low on the preferences of most employers except those in the engineering fields. Highly technological industries have expectations of mathematics students different from those of employers of 15-year-old school leavers. For the purpose of the investigation, Nisbet interviewed twelve business representatives from a range of occupations. He concluded that many of the interviewees had limited perceptions of basic skills (typically the four operations), and that these would be at variance with mathematics educators.

Hannan (1981) investigated specific areas of mathematical difficulties of Australian apprentices. More than 50% of apprentices failed on eight questions concerned with the areas: percentage; use of Pythagoras' Theorem; mathematical vocabulary; perimeter and area of a square; comparison of plane figures; simplification of algebraic expressions; substitution in formulae; and construction of a simple

formula. Since some of these topics are areas in which apprentices need a high level of competency to cope with their apprenticeships this is a matter of some concern. In particular, the majority of incoming apprentices would benefit from work with mathematical vocabulary, formulae and the solution of problems. She also considered selection of apprentices, motivation and assessment techniques, and suggested the need for general remedial mathematics programmes.

This section would be incomplete without a mention of the Careers and Mathematics (CAM) project supported by the Australian Institution of Engineers. This project, commenced in late 1982, aims to encourage and contribute to the development of an approach to school mathematics that emphasises the practical role that mathematics plays in modern industrialised society. In particular, the project intends to focus on the role that mathematics will play in the future careers of children currently in secondary schools and so is very much attuned to the needs of children entering the workforce. CAM has three major aims:

(i) to identify the mathematics that is currently taught in school and which is explicitly used in industry, by whom it is used, and how it is used;

(ii) to develop teaching and learning materials that present this mathematics in the context in which it is used in the workplace;

(iii) to identify elementary mathematical ideas and concepts used in ingenious ways to solve real problems in industry, and to present them in a form suitable for classroom use.

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